APPENDIX A
PERHITUNGAN NERACA MASSA

Waktu Operasi	=	330	hari/thn
Kapasitas Produksi	=	35000	ton/thn
	=	35000000	kg/thn
	=	3995.43379	kg/jam
Basis Asam Oleat	=	4263.319953	kg/jam

Komposisi Bahan Baku:

Komposisi Bahan Asam Oleat (PT. Cisande Raya)

Komponen	%Berat
$C_{18}H_{34}O_2$	99%
H_2O	1%

Komposisis Bahan Urea (PT.Pupuk Kujang Cikampek)

Komponen	%Berat
$CO(NH_2)_2$	99%
H_2O	1%

Komposisi Bahan Katalis (Xiamen Ditai Chemicals)

Komponen	%Berat
$ALCl_3$	99%
H_2O	1%

Komposisi Bahan Baku Pelarut Kloroform (PT. Shanghai S-ailing Chemical)

Komponen	%Berat
$CHCl_3$	98%
H_2O	1%

Komponen dan Berat Molekul

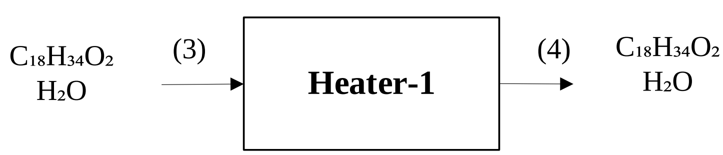
Komponen	Berat Molekul (kg/kmol)
$C_{18}H_{34}O_2$	282
$CO(NH_2)_2$	60
$C_{18}H_{35}NO$	281
$CHCl_3$	119
H_2O	18
CO_2	44
NH_3	17
$AlCl_3$	133

A. Perhitungan Neraca Massa Sebelum Recycle

1. Melter Urea (M-130)

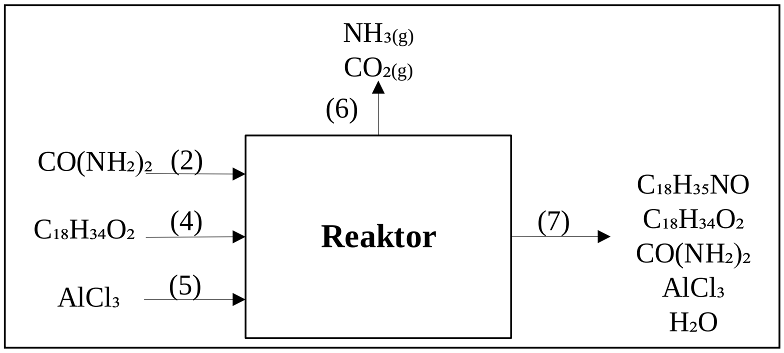
Neraca Melter Urea (M-130)		
	Massa Masuk (kg/jam)	**Massa Keluar (kg/jam)**
Komponen	**1**	**2**
$CO(NH_2)_2(_s)$	898.018	
$CO(NH_2)_2(_l)$		898.018
$H_2O(_l)$	9.0709	9.0709
Subtotal	**907.089**	**907.0894**
Total	**907.0894**	**907.0894**

2. Heater (E-122)



Neraca Heater (M-122)		
	Massa Masuk (kg/jam)	**Massa Keluar (kg/jam)**
Komponen	**3**	**4**
$C_{18}H_{34}O_2(_l)$	4220.687	4220.687
$H_2O(_l)$	42.6332	42.6332
Total	**4263.3200**	**4263.3200**

3. Reaktor (R-210)



Feed Masuk Reaktor

Perbandingan mol asam oleat dan urea 1 : 1 dengan konversi 95% **(U.S PATENT)**

Aliran 1

$C_{18}H_{34}O_2$ = Kemurnian x Basis

= 0.99 x 4263.32 kg/jam

= 4220.687 kg/jam

= 14.96697 kmol/jam

H_2O = $\dfrac{\text{Kemurnian } H_2O}{\text{Kemurnian } C_{18}H_{34}O_2}$ x Massa $C_{18}H_{34}O_2$

= $\dfrac{1\%}{99\%}$ x 4220.687 kg/jam

= 42.63 kg/jam

= 0.71 kmol/jam

Aliran 2

$CO(NH_2)_2$ = $\dfrac{\text{perbandingan mol } CO(NH_2)_2}{\text{perbandingan mol } C_{18}H_{34}O_2}$ x mol $C_{18}H_{34}O_2$

= $\dfrac{1}{1}$ x 14.967 kmol/jam

= 14.9670 kmol/jam

= 898.018 kg/jam

H_2O = $\dfrac{1\%}{99\%}$ x Massa $CO(NH_2)_2$

= 9.0709 kg/jam

Aliran 4

Kebutuhan Katalis: 1% wt (U.S Patent)

$AlCl_3$ = 1% x Massa $C_{18}H_{34}O_2$

= 0.01 x 4221 kg/jam

= 42.2 kg/jam

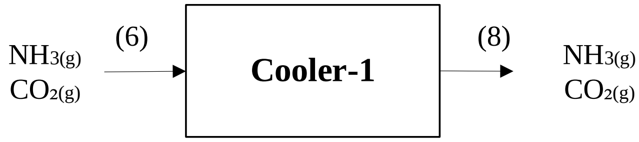
Konversi Reaksi: 95% (U.S Patent)
Stokiometri Reaksi: $AlCl_3$

	$C_{18}H_{34}O_2$ +	$CO(NH_2)_2$ →	$C_{18}H_{35}NO$ +	CO_2 +	NH_3
M	14.9670	14.9670	-	-	
R	14.2186	14.2186	14.2186	14.219	14.219
S	0.7483	0.7483	14.2186	14.219	14.219

Keluaran Reaktor
Aliran 4
CO_2 = 14.2186 kmol/jam
= 625.62 kg/jam
NH_3 = 14.2186 kmol/jam
= 241.72 kg/jam
Aliran 5
$C_{18}H_{35}NO$ = 14.2186 kmol/jam
= 3995.434 kg/jam
$C_{18}H_{34}O_2$ = 0.7483 kmol/jam
= 211.0343 kg/jam
$CO(NH_2)_2$ = 0.7483 kmol/jam
= 44.90092 kg/jam
$AlCl_3$ = 42.20687 kg/jam

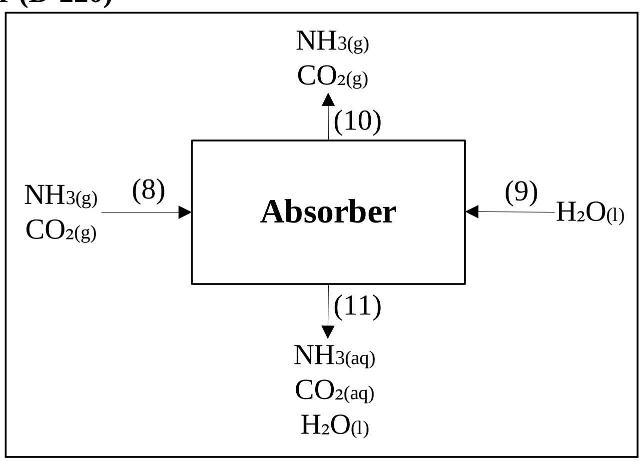
Neraca Massa Reaktor (R-210)					
	Massa Masuk (kg/jam)			Massa Keluar (kg/jam)	
Komponen	**2**	**4**	**5**	**6**	**7**
$C_{18}H_{35}NO_{(l)}$					3995.4338
$C_{18}H_{34}O_{2(l)}$		4220.687			211.03434
$CO(NH_2)_{2(l)}$	898.018				44.900923
$AlCl_{3(s)}$			42.20686753		42.206868
$CO_{2(g)}$				625.6195	
$NH_{3(g)}$				241.7166	
$H_2O_{(l)}$	9.0709	42.6332			51.7041
Subtotal	**907.0894**	**4263.32**	**42.20686753**	**867.3362**	**4345.28**
Total	**5212.6162**			**5212.6162**	

4. Cooler-1 (E-212)



Neraca Cooler-1 (E-212)		
	Massa Masuk (kg/jam)	**Massa Keluar (kg/jam)**
Komponen	**6**	**8**
$NH_3(_g)$	241.717	241.717
$H_2O(_l)$	625.6195	625.6195
Subtotal	**867.3362**	**867.3362**
Total	**867.3362**	**867.3362**

5 Absorber (D-220)



Efisiensi = 99% (Ludwig, 1999)

Aliran 6

H_2O yang dibutuhkan untuk menyerap NH_3 $= \dfrac{\text{Berat feed NH3} \times 100 \text{ kg } H_2O}{\text{Kelarutan } NH_3}$

$= \dfrac{241.7166 \times 100}{28.1}$

$= 860.2015$ kg/jam

H_2O yang dibutuhkan untuk menyerap CO_2 $= \dfrac{\text{Berat feed } CO_2 \times 100 \text{ kg } H_2O}{\text{Kelarutan } CO_2}$

$= \dfrac{625.6195 \times 100}{0.145}$

$= 431461.7420$ kg/jam

Total kebutuhan H_2O = 432321.9435 kg/jam

Aliran 7

CO_2 yang terserap = Efisiensi x Feed masuk CO_2
= 99% x 625.6195 kg/jam
= 619.3633 kg/jam

NH_3 yang terserap = Efisiensi x Feed masuk NH_3
= 99% x 241.7166 kg/jam
= 239.2995 kg/jam

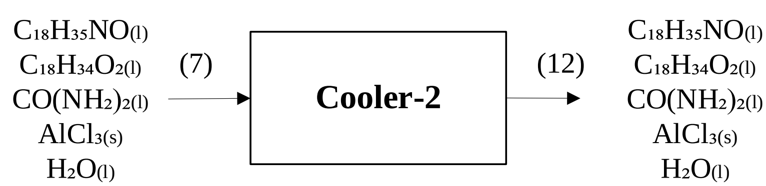
Aliran 8

CO_2 yang lolos = 1% x Feed masuk CO2
= 1% x 625.6195 kg/jam
= 6.2562 kg/jam

NH_3 yang lolos = 1% x Feed masuk NH_3
= 1% x 241.7166 kg/jam
= 2.4172 kg/jam

Neraca Massa Absorber (D-220)				
Komponen	**Massa Masuk (kg/jam)**		**Massa Keluar (kg/jam)**	
	8	**9**	**10**	**11**
$CO_2(_g)$	625.6195		6.2562	
$NH_3(_g)$	241.7166		2.4172	
$CO_2(_{aq})$				619.3633
$NH_3(_{aq})$				239.2995
$H_2O(_l)$		432321.9435		432321.94
Subtotal	**867.3362**	**432321.9435**	**8.6734**	**433180.61**
Total	**433189.2797**		**433189.2797**	

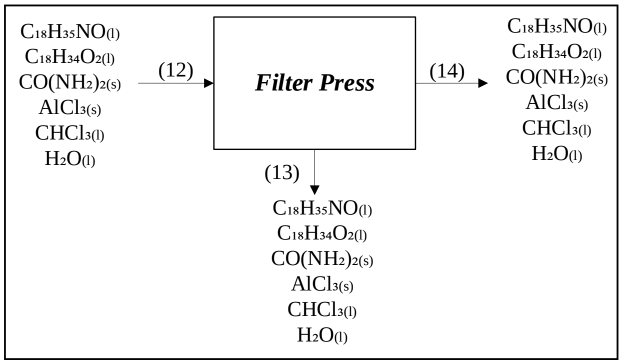
6. Cooler-2 (E-214)



Neraca Cooler-2 (E-212)		
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**
	7	**12**
$C_{18}H_{35}NO(_l)$	3995.434	3995.434
$C_{18}H_{34}O_2(_l)$	211.034	211.034
$CO(NH_2)_2$(s)	44.901	44.901

$AlCl_3(_s)$	42.207	42.207
H_2O	51.7041	51.704
Subtotal	**4345.280**	**4345.2800**
Total	**4345.2800**	**4345.2800**

7. Filter Press



Efisiensi Filter Press 99%

Aliran 14

Padatan

$AlCl_3$ = Efisiensi x Massa $AlCl_3$
= 99% x 42.2069 kg/jam
= 41.7848 kg/jam

$CO(NH_2)_2$ = Efisien x Massa $CO(NH_2)_2$
= 99% x 44.901 kg/jam
= 44.45191 kg/jam

Filtrat

$C_{18}H_{35}NO$ = Efisiensi x Massa $C_{18}H_{35}NO$
= 1% x 3995.434 kg/jam
= 39.95434 kg/jam

$C_{18}H_{34}O_2$ = Efisiensi x Massa $C_{18}H_{34}O_2$
= 1% x 211.034 kg/jam
= 2.110343 kg/jam

H_2O = Efisiensi x Massa H_2O
= 1% x 51.704 kg/jam
= 0.517041 kg/jam

Aliran 13

Padatan

$AlCl_3$ = Massa $AlCl_3$ - Massa $AlCl_3$ Aliran 11

= 42.2069 kg/jam - 41.7848 kg/jam
= 0.422069 kg/jam

$CO(NH_2)_2$ = Massa $CO(NH_2)_2$ - Massa $CO(NH_2)_2$ Aliran 11
= 44.901 kg/jam - 44.45191 kg/jam
= 0.449009 kg/jam

Filtrat

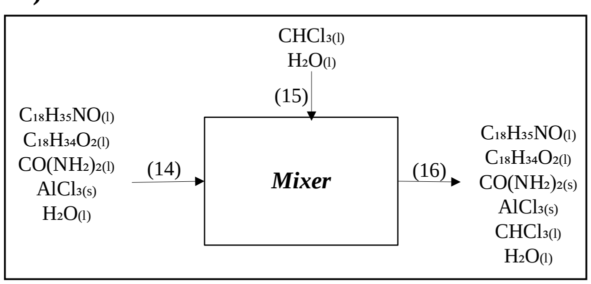
$C_{18}H_{35}NO$ = Massa $C_{18}H_{35}NO$ - Massa $C_{18}H_{35}NO$ Aliran 11
= 3995.434 kg/jam - 39.95434 kg/jam
= 3955.479 kg/jam

$C_{18}H_{34}O_2$ = Massa $C_{18}H_{34}O_2$ - Massa $C_{18}H_{34}O_2$ Aliran 11
= 211.034 kg/jam - 2.110343 kg/jam
= 208.924 kg/jam

H_2O = Massa H_2O - Massa H_2O Aliran 11
= 51.704 kg/jam - 0.517041 kg/jam
= 51.187 kg/jam

Neraca Massa Filter Press (H-320)			
Komponen	Massa Masuk (kg/jam)	Massa Keluar (kg/jam)	
	12	13	14
$C_{18}H_{35}NO_{(l)}$	3995.434	39.954	3955.479
$C_{18}H_{34}O_{2(l)}$	211.034	2.110343377	208.9239943
$CO(NH_2)_{2(s)}$	44.901	44.45191368	0.449009229
$AlCl_{3(s)}$	42.207	41.78479886	0.422068675
$H_2O_{(l)}$	51.704	0.51704093	51.187
Subtotal	**4345.280**	**128.818**	**4216.462**
Total	**4345.280**	**4345.280**	

8. Mixer (M-310)



Dilakukan penambahan klorofrom.
Kelatutan Oleamida dlam Kloroform = 50mg/ml

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

$$v = \frac{50 \text{ mg}}{940 \text{ mg/ml}}$$

= 0.05 ml

= 0.05 ml / ml

Kebutuhan Pelarut Sebelum Recycle

Aliran 15

$CHCl_3$ = 0.05 x Massa $C_{18}H_{35}NO$

= 0.05 x 3995.4338 kg/jam

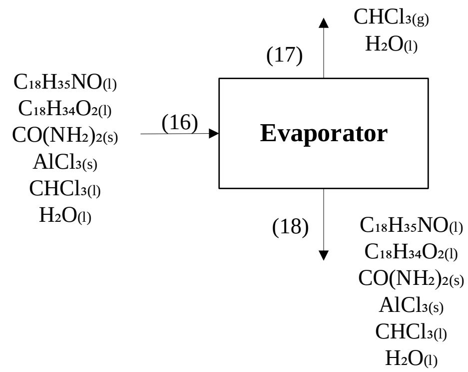
= 199.8 kg/jam

H_2O = 2% x Massa $CHCl_3$ yang masuk

= 79.90868 kg/jam

Neraca Massa Mixer			
Komponen	**Massa Masuk (kg/jam)**		**Massa Keluar (kg/jam)**
	14	**15**	**16**
$C_{18}H_{35}NO_{(l)}$	3955.479		3955.479452
$C_{18}H_{34}O_{2(l)}$	208.924		208.9239943
$CO(NH_2)_{2(s)}$	0.449		0.449
$AlCl_{3(s)}$	0.422		0.422
$CHCl_{3(l)}$		199.77	199.77
$H_2O_{(l)}$	51.7041	79.9086758	131.6128
Subtotal	**4216.97862**	**279.6803653**	**4496.658983**
Total	**4496.658983**		**4496.658983**

9. Evaporator (V-330)



Aliran Masuk Evaporator

Komponen	Massa (kg/jam)
$C_{18}H_{35}NO(_l)$	3955.479452
$C_{18}H_{34}O_2(_l)$	208.9239943
$CO(NH_2)_2(_s)$	0.449009229
$AlCl_3(_s)$	0.422068675
$CHCl_3(_l)$	199.7716895
$H_2O(_l)$	131.6127688
Total	**4496.658983**

Konsentrasi Feed Masuk : 19.8

Konsentrasi yang diharapkan saat keluar: 40%

Arus Keluar Ratio L/V (Efisiensi dari Evaporator 80%, Kern 1965, hal 455)

Komponen	%L	%V	L(Kmol/Jam)	V (Kmol/Jam)
Oleamida	100%	0%	14.07643933	0
Asam Oleat	100%	0%	0.740865228	0
Kloroform	20%	80%	0.335750739	1.343002955
Air	20%	80%	1.462364098	5.849456393
Total			**16.6154194**	**7.192459348**

Vapour

Komponen	(Kmol/Jar	Massa (Kg/Jam)
Oleamida	0	0
Asam Oleat	0	0
Kloroform	1.343003	159.8173516
Air	5.849456	105.2902151
Total	**7.192459**	**265.1075667**

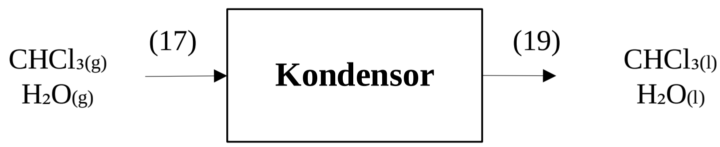
Liquid

Komponen	(Kmol/Jar	Massa (Kg/Jam)
Oleamida	14.07644	3955.479452
Asam Oleat	0.740865	208.9239943
Kloroform	0.335751	39.9543379
Air	1.462364	26.32255377
Total	**16.61542**	**4230.680338**

Neraca Massa Evaporator (V-330)			
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**	
	16	**17**	**18**
$C_{18}H_{35}NO(_l)$	3955.479452		3955.479452
$C_{18}H_{34}O_2(_l)$	208.9239943		208.9239943

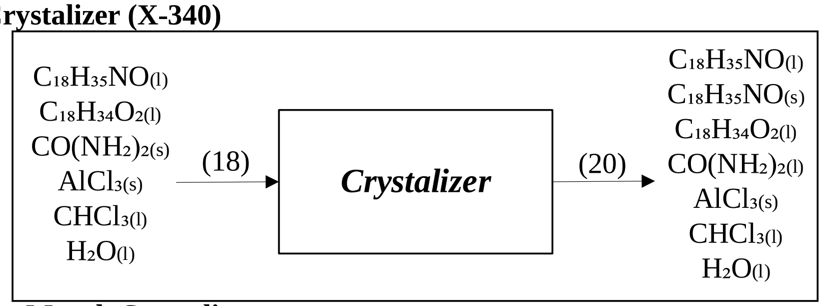
$CO(NH_2)_2(_s)$	0.449009229		0.449009229
$AlCl_3(_s)$	0.422068675		0.422068675
$CHCl_3(_l)$	199.7716895		39.9543379
$CHCl_3(_g)$		159.8173516	
$H_2O(_g)$		105.2902151	
$H_2O(_l)$	131.6127688		26.32255377
Subtotal	**4496.658983**	**265.1075667**	**4231.551416**
Total	**4496.658983**	**4496.658983**	

10. Kondensor (E-331)



Neraca Kondensor (E-331)		
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**
	17	**19**
$CHCl_3(_g)$	159.817	
$H_2O(_g)$	105.2902	
$CHCl_3(_l)$		159.8174
$H_2O(_l)$		105.2902
Subtotal	**265.1076**	**265.1076**
Total	**265.1076**	**265.1076**

11. Crystalizer (X-340)



Aliran Masuk Crystalizer

Komponen	Massa (kg/jam)
$C_{18}H_{35}NO(_l)$	3955.479452
$C_{18}H_{34}O_2(_l)$	208.9239943
$CO(NH_2)_2(_s)$	0.449009229
$AlCl_3(_s)$	0.422068675

$CHCl_3(l)$	39.9543379
$H_2O(l)$	26.32255377
Subtotal	**4231.551416**

Perhitungan Kristal yang Terbentuk

$$P = R \times \frac{100W_0 - S\,(H_0 - E)}{100 - S\,(R - 1)}$$

Dimana :
- P = Berat kristal
- R = Rasio BM dari kristal / larutan
- S = Solubility kristal pada mother liquor
- W_0 = Berat bahan yang akan dikristalkan pada feed
- H_0 = Total bahan yang bersifat liquid pada feed
- E = Evaporation

Solubility kristal pada mother liquor (S) :

pada (suhu 50°C) = 50 mg/ml
= 0.033784 kg/kg

Berat Oleamida yang akan dikristalkan pada feed (Wo) :

Wo = 3955.5 Kg/Jam

Total bahan yang bersifat liquid pada feed (Ho) :

Ho = 4231.5514

Evaporation (E) :

E = pelarut yang menguap = 0 kg (Crytalizer berpedingin sehingga tidak ada penguapan)

Maka, jumlah kristal yang terbentuk :

$$P = R \times \frac{100W_0 - S\,(H_0 - E)}{100 - S\,(R - 1)}$$

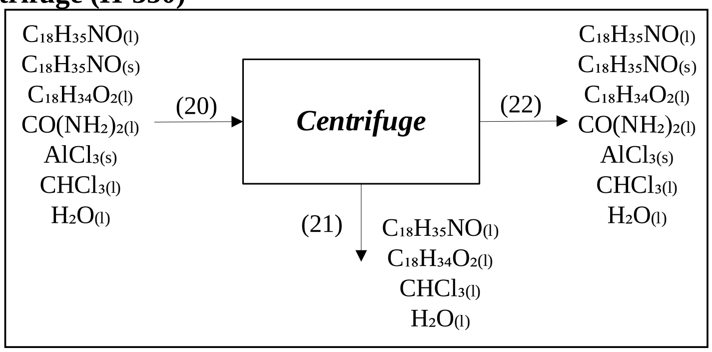
$$= 1 \times \frac{100 \times 3955.48 - 0.0338\ (4231.551 - 0)}{100 - 0.0338\ (1 - 1)}$$

= 3954.0499 Kg/Jam

Neraca Massa Crystalizer (X-340)		
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**
	18	**20**
$C_{18}H_{35}NO_{(l)}$	3955.479452	1.4296
$C_{18}H_{35}NO_{(s)}$	-	3954.0499
$C_{18}H_{34}O_2(l)$	208.9239943	208.9239943

$CO(NH_2)_2(_s)$	0.449009229	0.449009229
$AlCl_3(_s)$	0.422068675	0.422068675
$CHCl_3(_l)$	39.9543379	39.9543379
$H_2O(_l)$	26.32255377	26.32255377
Total	**4231.551416**	**4231.551416**

12. Centrifuge (H-350)



Aliran Masuk Centrifuge

Komponen	Massa (kg/jam)
$C_{18}H_{35}NO_{(l)}$	1.4296
$C_{18}H_{35}NO_{(s)}$	3954.0499
$C_{18}H_{34}O_{2(l)}$	208.9240
$CO(NH_2)_{2(s)}$	0.4490
$AlCl_{3(s)}$	0.4221
$CHCl_{3(l)}$	39.9543
$H_2O_{(l)}$	26.3226
Subtotal	4231.5514

2-10% terdapat liquid melekat pada permukaan kristal **(Perry 7ed : 18-43)**

Liquid yang terikut solid= 5%

Aliran 22

Padatan

Massa $C_{18}H_{35}N$(= 3954.0499 kg/jam

Massa $CO(NH_2)$ = 0.4490 kg/jam

Massa $AlCl_{3(s)}$ = 0.4221 kg/jam

Cairan

Massa $C_{18}H_{35}N$(= 5% x Jumlah Massa Liquid

= 5% x 1.4296 kg/jam

= 0.071 kg/jam

Massa $C_{18}H_{34}O_2$ = 5% x Jumlah Massa Liquid

= 5% x 208.924 kg/jam

= 10.446 kg/jam

Massa $CHCl_{3(l)}$ = 5% x Jumlah Massa Liquid
= 5% x 39.954 kg/jam
= 1.998 kg/jam

Massa $H_2O_{(l)}$ = 5% x Jumlah Massa Liquid
= 5% x 26.3226 kg/jam
= 1.316 kg/jam

Aliran 21

Massa $C_{18}H_{35}N$(= Massa $C_{18}H_{35}NO_{(l)}$ masuk - Massa $C_{18}H_{35}NO_{(l)}$ aliran 17
= 1.4296 kg/jam - 0.071 kg/jam
= 1.358 kg/jam

Massa $C_{18}H_{34}O_2$ = Massa $C_{18}H_{34}O_{2(l)}$ masuk - Massa $C_{18}H_{34}O_{2(l)}$ aliran 17
= 208.924 kg/jam - 10.446 kg/jam
= 198.478 kg/jam

Massa $CHCl_{3(l)}$ = Massa $CHCl_{3(l)}$ masuk - Massa $CHCl_{3(l)}$ aliran 17
= 39.9543 kg/jam - 1.998 kg/jam
= 37.957 kg/jam

Massa $H_2O_{(l)}$ = Massa H_2O masuk - Massa H_2O aliran 16
= 26.3226 kg/jam - 1.316 kg/jam
= 25.0064 kg/jam

Neraca Massa Centrifuge (H-350)			
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**	
	20	**21**	**22**
$C_{18}H_{35}NO_{(l)}$	1.4296	1.358	0.071
$C_{18}H_{35}NO_{(s)}$	3954.0499		3954.0499
$C_{18}H_{34}O_{2(l)}$	208.9240	198.478	10.446
$CO(NH_2)_{2(s)}$	0.4490		0.4490
$AlCl_{3(s)}$	0.4221		0.422068675
$CHCl_{3(l)}$	39.9543	37.957	1.998
$H_2O_{(l)}$	26.3226	25.0064	1.316
Subtotal	**4231.5514**	**262.7989**	**3968.752**
Total	**4231.5514**	**4231.5514**	

13. Molecular Sieve (D-362)

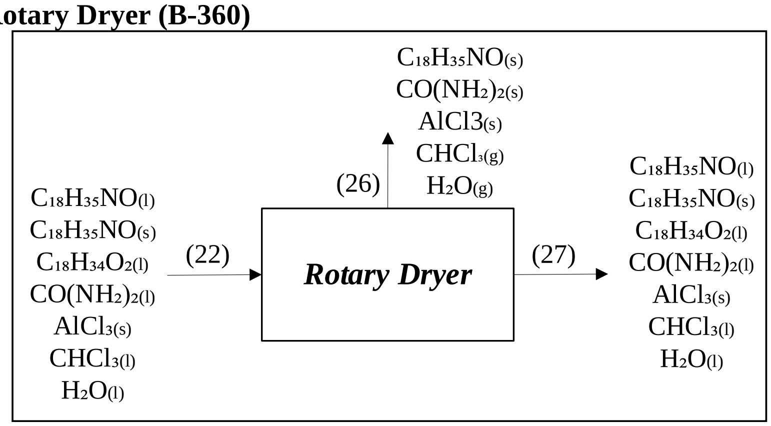
Neraca Massa Molecular Sieve (D-362)			
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**	
	23	**24**	**Terserap**

Udara Bebas	3319.170491		
Udara Kering		3236.941361	
$H_2O_{(l)}$			82.22913
Total	**3319.170491**	**3319.170491**	

14. Heater-2 (E-363)

Neraca Heater (E-363)		
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**
	24	**25**
Udara kering	3236.941	3236.941
Total	**3236.9414**	**3236.9414**

15. Rotary Dryer (B-360)



Aliran Masuk Rotar Dryer

Komponen	Massa (kg/jam)
$C_{18}H_{35}NO_{(l)}$	0.071
$C_{18}H_{35}NO_{(s)}$	3954.050
$C_{18}H_{34}O_{2(l)}$	10.446
$CO(NH_2)_{2(s)}$	0.449
$AlCl_{3(s)}$	0.422
$CHCl_{3(l)}$	1.998
$H_2O_{(l)}$	1.316
Total	**3968.752**

Aliran 26

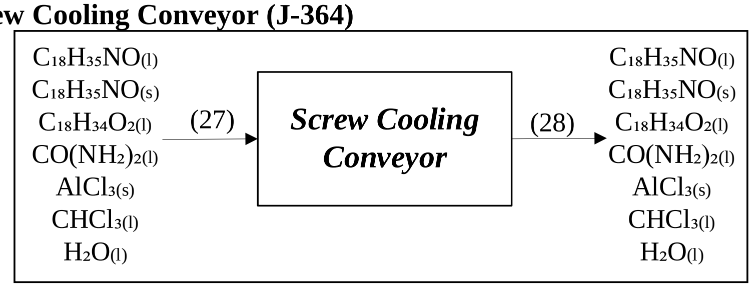
Solid terbawa udara = 1% **(0,02-0,2%; Ludwig Vol.1; 4thed; Hal-422)**
H_2O Teruapkan = 95%
$CHCl_{3(l)}$ Teruapkan = 95%

Solid terbawa udara

$C_{18}H_{35}NO_{(s)}$ = 1% x 3954.050 = 39.5404987 kg/jam
$CO(NH_2)_{2(s)}$ = 1% x 0.449 = 0.00449009 kg/jam
$AlCl_{3(s)}$ = 1% 0.422 = 0.00422069 kg/jam
H_2O Teruapkan = 95% x 1.316 = 1.2503213 kg/jam
$CHCl_{3(l)}$ Teruapkan = 95% x 1.998 = 1.8978311 kg/jam

Neraca Massa Rotary Dryer (B-360)			
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**	
	22	**26**	**27**
$C_{18}H_{35}NO_{(l)}$	0.0715		0.071
$C_{18}H_{35}NO_{(s)}$	3954.0499	39.54049874	3914.5094
$C_{18}H_{34}O_{2(l)}$	10.4462		10.446
$CO(NH_2)_{2(s)}$	0.4490	0.004490092	0.4445
$AlCl_{3(s)}$	0.4221	0.004220687	0.4178
$CHCl_{3(l)}$	1.9977	1.898	0.100
$H_2O_{(l)}$	1.3161	1.2503	0.066
Total	**3968.7525**	**42.6974**	**3926.055**
Subtotal	**3968.7525**	**3968.7525**	

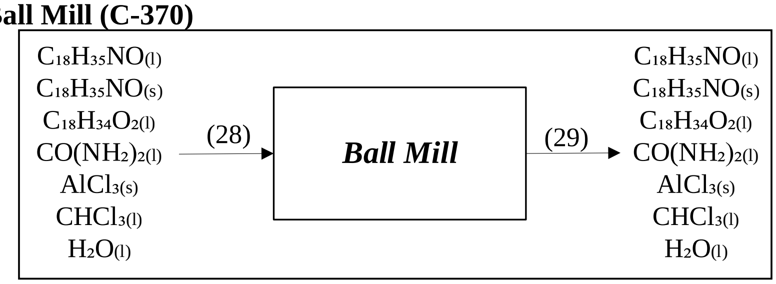
16. Screw Cooling Conveyor (J-364)



Neraca Massa Screw Cooling Conveyor (J-364)		
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**
	27	**28**
$C_{18}H_{35}NO_{(l)}$	0.0715	0.0715
$C_{18}H_{35}NO_{(s)}$	3914.5094	3914.5094
$C_{18}H_{34}O_{2(l)}$	10.4462	10.4462
$CO(NH_2)_{2(s)}$	0.4445	0.4445

$AlCl_{3(s)}$	0.4178	0.4178
$CHCl_{3(l)}$	0.0999	0.0999
$H_2O_{(l)}$	0.0658	0.0658
Total	**3926.0551**	**3926.0551**
Subtotal	**3926.0551**	**3926.0551**

17. Ball Mill (C-370)



Neraca Massa Ball Mill (C-370)		
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**
	28	**29**
$C_{18}H_{35}NO_{(l)}$	0.0715	0.0715
$C_{18}H_{35}NO_{(s)}$	3914.5094	3914.5094
$C_{18}H_{34}O_{2(l)}$	10.4462	10.4462
$CO(NH_2)_{2(s)}$	0.4445	0.4445
$AlCl_{3(s)}$	0.4178	0.4178
$CHCl_{3(l)}$	0.0999	0.0999
$H_2O_{(l)}$	0.0658	0.0658
Subtotal	**3926.0551**	**3926.0551**
Total	**3926.0551**	**3926.0551**

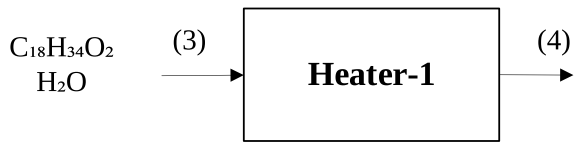
B. Perhitungan Neraca Massa Setelah Recycle

1. Melter Urea (M-130)

Neraca Melter Urea (M-130)		
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**
	1	**2**
$CO(NH_2)_2(_s)$	898.018	

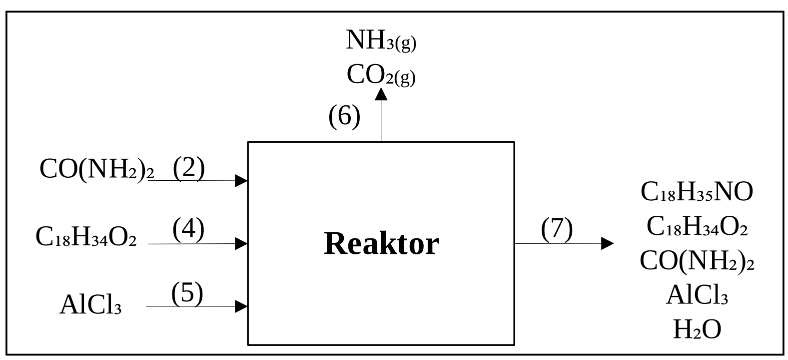
$CO(NH_2)_{2(l)}$		898.018
$H_2O_{(l)}$	9.071	9.0709
Subtotal	**907.089**	**907.0894**
Total	**907.0894**	**907.0894**

2. Heater (E-122)



Neraca Heater (E-122)		
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**
	3	**4**
$C_{18}H_{34}O_{2(l)}$	4220.687	4220.687
$H_2O_{(l)}$	42.633	42.6332
Total	**4263.3200**	**4263.3200**

3. Reaktor (R-210)



Feed Masuk Reaktor

Perbandingan mol asam oleat dan urea 1 : 1 dengan konversi 95% **(U.S PATENT**

Aliran 4

$$C_{18}H_{34}O_2 = \text{Kemurnian} \times \text{Basis}$$
$$= 0.99 \times 4263.32 \text{ kg/jam}$$
$$= 4220.687 \text{ kg/jam}$$
$$= 14.96697 \text{ kmol/jam}$$

$$H_2O = \frac{\text{Kemurnian } H_2O}{\text{Kemurnian } C_{18}H_{34}O_2} \times \text{Massa } C_{18}H_{34}O_2$$
$$= \frac{1\%}{99\%} \times 4220.687 \text{ kg/jam}$$
$$= 42.63 \text{ kg/jam}$$

= 2.37 kmol/jam

Aliran 2

$CO(NH_2)_2 = \dfrac{\text{perbandingan mol } CO(NH_2)_2}{\text{perbandingan mol } C_{18}H_{34}O_2} \times \text{mol } C_{18}H_{34}O_2$

$= \dfrac{1}{1} \times 14.967$ kmol/jam

= 14.9670 kmol/jam

= 898.018 kg/jam

$H_2O = \dfrac{1\%}{99\%} \times \text{Massa } CO(NH_2)_2$

= 9.0709 kg/jam

Aliran 4

Kebutuhan Katalis: 1% wt (U.S Patent)

$AlCl_3$ = 1% x Massa $C_{18}H_{34}O_2$

= 0.01 x 4221 kg/jam

= 42.2 kg/jam

Konversi Reaksi: 95% (U.S Patent)

Stokiometri Reaksi:

$C_{18}H_{34}O_2 + CO(NH_2)_2 \longrightarrow C_{18}H_{35}NO + CO_2 + NH_3$

	$C_{18}H_{34}O_2$	$CO(NH_2)_2$	$C_{18}H_{35}NO$	CO_2	NH_3
M	14.9670	14.9670	-	-	
R	14.2186	14.2186	14.2186	14.219	14.219
S	0.7483	0.7483	14.2186	14.219	14.219

Keluaran Reaktor

Aliran 4

CO_2 = 14.2186 kmol/jam

= 625.62 kg/jam

NH_3 = 14.2186 kmol/jam

= 241.72 kg/jam

Aliran 5

$C_{18}H_{35}NO$ = 14.2186 kmol/jam

= 3995.434 kg/jam

$C_{18}H_{34}O_2$ = 0.7483 kmol/jam

= 211.0343 kg/jam

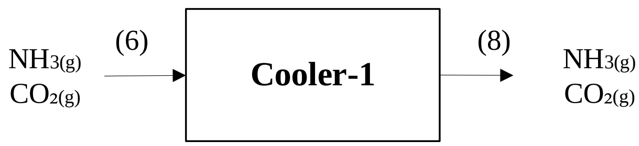
$CO(NH_2)_2$ = 0.7483 kmol/jam

= 44.90092 kg/jam

$AlCl_3$ = 42.20687 kg/jam

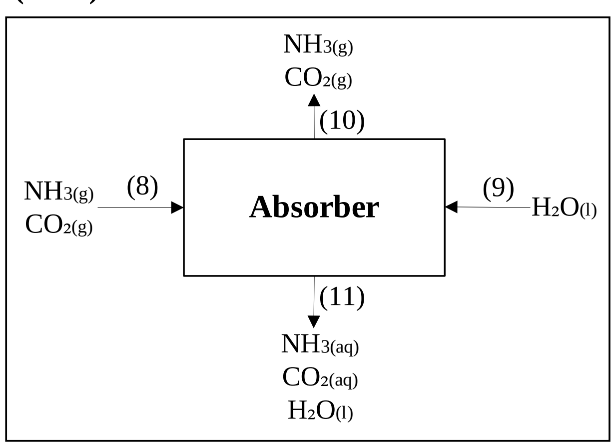
Neraca Massa Reaktor (R-210)					
Komponen	Massa Masuk (kg/jam)			Massa Keluar (kg/jam)	
	2	4	5	6	7
$C_{18}H_{35}NO_{(l)}$					3995.4338
$C_{18}H_{34}O_2(_l)$		4220.687			211.03434
$CO(NH_2)_2(_l)$	898.018				44.900923
$AlCl_3(_s)$			42.20686753		42.206868
$CO_2(_g)$				625.6195	
$NH_3(_g)$				241.7166	
$H_2O(_l)$	9.0709	42.6332			51.7041
Subtotal	**907.0894**	**4263.32**	**42.20686753**	**867.3362**	**4345.28**
Total	**5212.6162**			**5212.6162**	

4. Cooler-1 (E-212)



Neraca Cooler-1 (E-212)		
Komponen	Massa Masuk (kg/jam)	Massa Keluar (kg/jam)
	6	8
$NH_3(_g)$	241.717	241.717
$CO_2(_g)$	625.6195	625.6195
Subtotal	**867.3362**	**867.3362**
Total	**867.3362**	**867.3362**

5 Absorber (D220)



Efisiensi = 99% (Ludwig, 1999)

Aliran 6

H_2O yang dibutuhkan untuk menyerap NH_3

$$= \frac{\text{Berat feed NH3} \times 100 \text{ kg } H_2O}{\text{Kelarutan } NH_3}$$

$$= \frac{241.7166 \times 100}{28.1000}$$

$$= 860.2015 \text{ kg/jam}$$

H_2O yang dibutuhkan untuk menyerap CO_2

$$= \frac{\text{Berat feed } CO_2 \times 100 \text{ kg } H_2O}{\text{Kelarutan } NH_3}$$

$$= \frac{625.6195 \times 100}{0.1450}$$

$$= 431461.7420 \text{ kg/jam}$$

Total kebutuhan H_2O = 432321.9435 kg/jam

Aliran11

CO_2 yang terserap = Efisiensi x Feed masuk CO_2
= 99% x 625.6195 kg/jam
= 619.3633 kg/jam

NH_3 yang terserap = Efisiensi x Feed masuk NH_3
= 99% x 241.7166 kg/jam
= 239.2995 kg/jam

Aliran 10

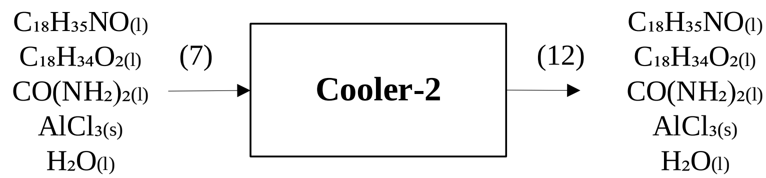
CO_2 yang lolos = 1% x Feed masuk CO2
= 1% x 625.6195 kg/jam
= 6.2562 kg/jam

NH_3 yang lolos = 1% x Feed masuk NH_3
= 1% x 241.7166 kg/jam
= 2.4172 kg/jam

Neraca Massa Absorber (D-220)

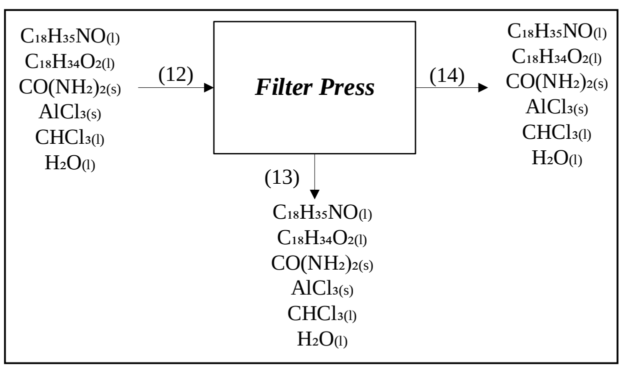
Komponen	**Massa Masuk (kg/jam)**		**Massa Keluar (kg/jam)**	
	8	**9**	**10**	**11**
$CO_2(_g)$	625.6195		6.2562	
$NH_3(_g)$	241.7166		2.4172	
$CO_2(_{aq})$				619.3633
$NH_3(_{aq})$				239.2995
$H_2O(_l)$		432321.9435		432321.94
Subtotal	**867.3362**	**432321.9435**	**8.6734**	**433180.61**
Total	**433189.2797**		**433189.2797**	

6. Cooler-2 (E-214)



Neraca Cooler (E-212)		
	Massa Masuk (kg/jam)	**Massa Keluar (kg/jam)**
Komponen	**7**	**12**
$C_{18}H_{35}NO_{(l)}$	3995.434	3995.434
$C_{18}H_{34}O_{2(l)}$	211.034	211.034
$CO(NH_2)_{2(l)}$	44.901	44.901
$AlCl_{3(s)}$	42.207	42.207
H_2O	51.7041	51.704
Subtotal	**4345.280**	**4345.2800**
Total	**4345.2800**	**4345.2800**

7. Filter Press



Efisiensi Filter Press 99%

Aliran 14

Padatan

$AlCl_3$ = Efisiensi x Massa $AlCl_3$
= 99% x 42.2069 kg/jam
= 41.7848 kg/jam

$CO(NH_2)_2$ = Efisien x Massa $CO(NH_2)_2$
= 99% x 44.901 kg/jam
= 44.45191 kg/jam

Filtrat

$C_{18}H_{35}NO$	=	Efisiensi	x	Massa $C_{18}H_{35}NO$	
	=	1%	x	3995.434	kg/jam
	=	39.95434 kg/jam			
$C_{18}H_{34}O_2$	=	Efisiensi	x	Massa $C_{18}H_{34}O_2$	
	=	1%	x	211.034	kg/jam
	=	2.110343 kg/jam			
H_2O	=	Efisiensi	x	Massa H_2O	
	=	1%	x	51.704	kg/jam
	=	0.517041 kg/jam			

Aliran 13
Padatan

$AlCl_3$	=	Massa $AlCl_3$	-	Massa $AlCl_3$ Aliran 11
	=	42.2069 kg/jam	-	41.7848 kg/jam
	=	0.422069 kg/jam		
$CO(NH_2)_2$	=	Massa $CO(NH_2)_2$	-	Massa $CO(NH_2)_2$ Aliran 11
	=	44.901 kg/jam	-	44.45191 kg/jam
	=	0.449009 kg/jam		

Filtrat

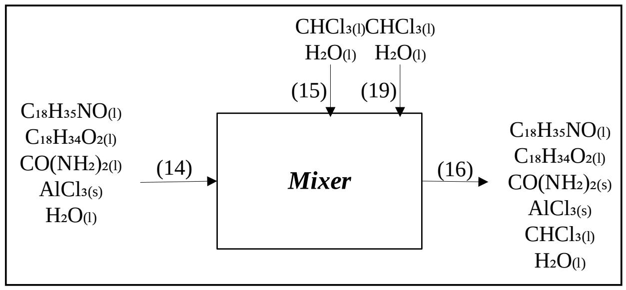
$C_{18}H_{35}NO$	=	Massa $C_{18}H_{35}NO$	-	Massa $C_{18}H_{35}NO$ Aliran 11
	=	3995.434 kg/jam	-	39.95434 kg/jam
	=	3955.479 kg/jam		
$C_{18}H_{34}O_2$	=	Massa $C_{18}H_{34}O_2$	-	Massa $C_{18}H_{34}O_2$ Aliran 11
	=	211.034 kg/jam	-	2.110343 kg/jam
	=	208.924 kg/jam		
H_2O	=	Massa H_2O	-	Massa H_2O Aliran 11
	=	51.704 kg/jam	-	0.517041 kg/jam
	=	51.187 kg/jam		

Neraca Massa Filter Press (H-320)

Komponen	Massa Masuk (kg/jam)	Massa Keluar (kg/jam)	
	12	13	14
$C_{18}H_{35}NO_{(l)}$	3995.434	39.954	3955.479
$C_{18}H_{34}O_{2(l)}$	211.034	2.110343377	208.9239943
$CO(NH_2)_{2(s)}$	44.901	44.45191368	0.449009229
$AlCl_{3(s)}$	42.207	41.78479886	0.422068675
$H_2O_{(l)}$	51.704	0.51704093	51.187

Subtotal	**4345.280**	**128.818**	**4216.462**
Total	**4345.280**	**4345.280**	

8. Mixer (M-310)



Kebutuhan Pelarut Setelah Recycle

Dilakukan penambahan klorofrom.

Kelatutan Oleamida dlam Kloroform = 50mg/ml

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

$v = \frac{50 \text{ mg}}{940 \text{ mg/ml}}$

= 0.05 ml

= 0.05 ml / ml

Kebutuhan Pelarut Sebelum Recycle

Aliran 15

$CHCl_3$ = 0.05 x Massa $C_{18}H_{35}NO$

= 0.05 x 3955.4795 kg/jam

= 197.8 kg/jam

H_2O = 2% x Massa $CHCl_3$ yang masuk

= 79.10959 kg/jam

Kebutuhan pelarut Setelah Recycle

$CHCL_3$ Keluaran Kondensor Aliran 19

$CHCl_3$ = 159.8174 kg/jam

Kebutuhan Pelarut

$CHCl_3$ yang dibutuhkan untuk *Make-up:*

$CHCl_3$ = Massa Kebutuhan $CHCl_3$ - Massa $CHCl_3$ Aliran 19

= 197.7740 kg/jam - 159.8173516 kg/jam

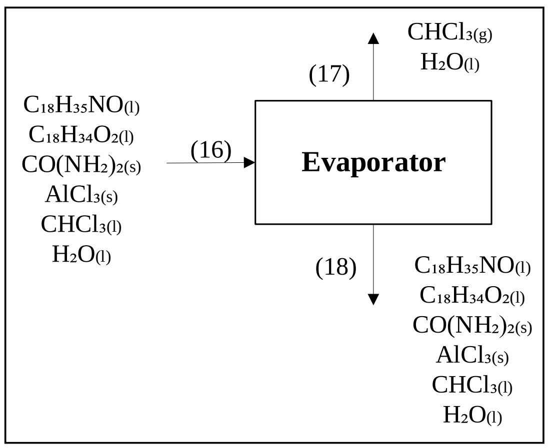
= 37.9566 kg/jam

H_2O = 2% x Massa $CHCl_3$ yang masuk

= 0.75913 kg/jam

Neraca Massa Mixer				
Komponen	**Massa Masuk (kg/jam)**			**Massa Keluar (kg/jam)**
	14	**15**	**19**	**16**
$C_{18}H_{35}NO$	3955.479			3955.479
$C_{18}H_{34}O_2$	208.924			208.924
$CO(NH_2)_2$	0.449			0.449
$AlCl_3$	0.422			0.422
$CHCl_3$		37.96	159.82	197.774
H_2O	51.187	0.759132	3.261579	55.208
Subtotal	**4216.462**	**38.71575**	**163.08**	**4418.25626**
Total	**4418.256**			**4418.256**

9. Evaporator (V-330)



Aliran Masuk Evaporator

Komponen	**Massa (kg/jam)**
$C_{18}H_{35}NO_{(l)}$	3955.479
$C_{18}H_{34}O_{2(l)}$	208.924
$CO(NH_2)_{2(s)}$	0.449
$AlCl_{3(s)}$	0.422
$CHCl_{3(l)}$	197.774
$H_2O_{(l)}$	55.208
Total	4418.256

Konsentrasi Feed Masuk : 8.9526%
Konsentrasi yang diharapkan saat keluar: 40%

Arus Keluar Ratio L/V (Efisiensi dari Vaporizer 80%, Kern 1965, hal 455)

Komponen	%L	%V	L(Kmol/Jam)	V (Kmol/Jam)
Oleamida	100%	0%	14.07643933	0
Asam Oleat	100%	0%	0.740865228	0
Kloroform	20%	80%	0.332393231	1.329572925
Air	20%	80%	0.61341959	2.453678362
Total			15.76311738	3.783251287

Vapour

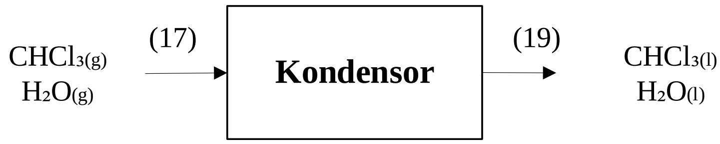
Komponen	(Kmol/Jar	Massa (Kg/Jam)
Oleamida	0	0
Asam Oleat	0	0
Kloroform	1.329573	158.2191781
Air	2.453678	44.16621051
Total	**3.783251**	**202.3853886**

Liquid

Komponen	(Kmol/Jar	Massa (Kg/Jam)
Oleamida	14.07644	3955.479452
Asam Oleat	0.740865	208.9239943
Kloroform	0.332393	39.55479452
Air	0.61342	11.04155263
Total	**15.76312**	**4214.999794**

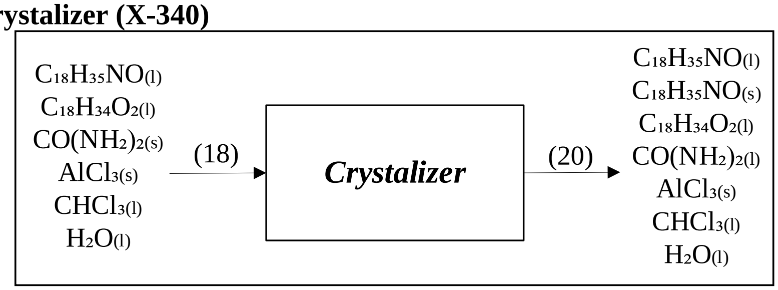
Neraca Massa Evaporator (V-330)			
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**	
	16	**17**	**18**
$C_{18}H_{35}NO_{(l)}$	3955.479452		3955.479452
$C_{18}H_{34}O_{2(l)}$	208.9239943		208.9239943
$CO(NH_2)_{2(s)}$	0.449009229		0.449009229
$AlCl_{3(s)}$	0.422068675		0.422068675
$CHCl_{3(l)}$	197.7739726	158.2191781	39.55479452
$H_2O_{(l)}$	55.20776314	44.16621051	11.04155263
Subtotal	**4418.25626**	**202.3853886**	**4215.870871**
Total	**4418.25626**	**4418.25626**	

10. Kondensor (E-331)



Neraca Kondensor (E-331)		
	Massa Masuk (kg/jam)	**Massa Keluar (kg/jam)**
Komponen	**17**	**19**
$CHCl_3(_g)$	158.219	
$H_2O(_g)$	44.1662	
$CHCl_3(_l)$		158.2192
$H_2O(_l)$		44.1662
Subtotal	**202.3854**	**202.3854**
Total	**202.3854**	**202.3854**

11. Crystalizer (X-340)



Aliran Masuk Crystalizer

Komponen	Massa (kg/jam)
$C_{18}H_{35}NO_{(l)}$	3955.479452
$C_{18}H_{34}O_{2(l)}$	208.9239943
$CO(NH_2)_{2(s)}$	0.449009229
$AlCl_{3(s)}$	0.422068675
$CHCl_{3(l)}$	39.55479452
$H_2O_{(l)}$	11.04155263
Subtotal	**4215.870871**

Perhitungan Kristal yang Terbentuk

$$P = R \times \frac{100W_0 - S\,(H_0 - E)}{100 - S\,(R - 1)}$$

Dimana : P = Berat kristal
R = Rasio BM dari kristal / larutan
S = Solubility kristal pada mother liquor

W_0 = Berat bahan yang akan dikristalkan pada feed
H_0 = Total bahan yang bersifat liquid pada feed
E = Evaporation

Solubility kristal pada mother liquor (S) :

pada (suhu 30^{o}C) = 50 mg/ml
= 0.033784 kg/kg

Berat Oleamida yang akan dikristalkan pada feed (Wo) :

Wo = 3955.5 Kg/Jam

Total bahan yang bersifat liquid pada feed (Ho) :

Ho = 4215.8709

Evaporation (E) :

E = pelarut yang menguap = 0 kg (Crytalizer berpedingin sehingga tidak ada penguapan)

Maka, jumlah kristal yang terbentuk :

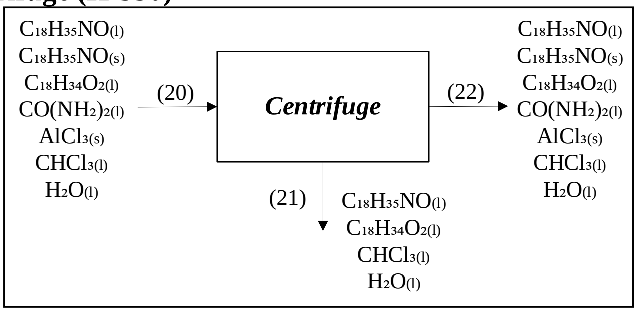
$$P = R \times \frac{100W_0 - S\,(H_0 - E)}{100 - S\,(R - 1)} \qquad 0.9996399$$

$$= 1 \times \frac{100 \times 3955.48 - 0.0338\,(4215.871 - 0}{100 - 0.0338\,(1 - 1)}$$

= 3954.0552 Kg/Jam

Neraca Massa Crystalizer (X-340)		
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**
	18	**20**
$C_{18}H_{35}NO_{(l)}$	3955.479452	1.4243
$C_{18}H_{35}NO_{(s)}$	-	3954.0552
$C_{18}H_{34}O_2$	208.9239943	208.9239943
$CO(NH_2)_2$	0.449009229	0.449009229
$AlCl_3$	0.422068675	0.422068675
$CHCl_3$	39.55479452	39.55479452
H_2O	11.04155263	11.04155263
Subtotal	**4215.870871**	**4215.870871**

12. Centrifuge (H-350)



Aliran Masuk Centrifuge

Komponen	Massa (kg/jam)
$C_{18}H_{35}NO_{(l)}$	1.4243
$C_{18}H_{35}NO_{(s)}$	3954.0552
$C_{18}H_{34}O_{2(l)}$	208.9240
$CO(NH_2)_{2(s)}$	0.4490
$AlCl_{3(s)}$	0.4221
$CHCl_{3(l)}$	39.5548
$H_2O_{(l)}$	11.0416
Total	**4215.8709**

2-10% terdapat liquid melekat pada permukaan kristal **(Perry 7ed : 18-43)**

Asumsi liquid yang terikut solid= 5%

Aliran 22

Padatan

Massa $C_{18}H_{35}NC$ = 3954.0552 kg/jam

Massa $CO(NH_2)$ = 0.4490 kg/jam

Massa $AlCl_{3(s)}$ = 0.4221 kg/jam

Cairan

Massa $C_{18}H_{35}NC$ = 5% x Jumlah Massa Liquid
= 5% x 1.4243 kg/jam
= 0.071 kg/jam

Massa $C_{18}H_{34}O_2$ = 5% x Jumlah Massa Liquid
= 5% x 208.924 kg/jam
= 10.446 kg/jam

Massa $CHCl_{3(l)}$ = 5% x Jumlah Massa Liquid
= 5% x 39.555 kg/jam
= 1.978 kg/jam

Massa $H_2O_{(l)}$ = 5% x Jumlah Massa Liquid
= 5% x 11.0416 kg/jam
= 0.552 kg/jam

Aliran 21

Massa $C_{18}H_{35}NO_{(}$ = Massa $C_{18}H_{35}NO_{(l)}$ masuk - Massa $C_{18}H_{35}NO_{(l)}$ aliran 22
= 1.4243 kg/jam - 0.071 kg/jam
= 1.353 kg/jam

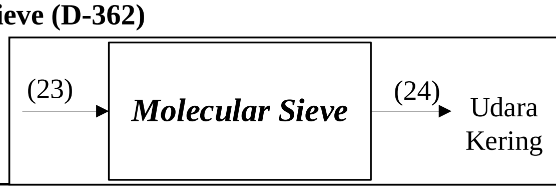
Massa $C_{18}H_{34}O_{2(l)}$ = Massa $C_{18}H_{34}O_{2(l)}$ masuk - Massa $C_{18}H_{34}O_{2(l)}$ aliran 22
= 208.924 kg/jam - 10.446 kg/jam
= 198.478 kg/jam

Massa $CHCl_{3(l)}$ = Massa $CHCl_{3(l)}$ masuk - Massa $CHCl_{3(l)}$ aliran 22
= 39.5548 kg/jam - 1.978 kg/jam
= 37.577 kg/jam

Massa $H_2O_{(l)}$ = Massa H_2O masuk - Massa H_2O aliran 22
= 11.0416 kg/jam - 0.552 kg/jam
= 10.4895 kg/jam

Neraca Massa Centrifuge (H-350)			
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**	
	20	**21**	**22**
$C_{18}H_{35}NO_{(l)}$	1.4243	1.353	0.071
$C_{18}H_{35}NO_{(s)}$	3954.0552		3954.0552
$C_{18}H_{34}O_{2(l)}$	208.9240	198.478	10.446
$CO(NH_2)_{2(s)}$	0.4490		0.4490
$AlCl_{3(s)}$	0.4221		0.422068675
$CHCl_{3(l)}$	39.5548	37.577	1.978
$H_2O_{(l)}$	11.0416	10.4895	0.552
Total	**4215.8709**	**247.8974**	**3967.973**
Subtotal	**4215.8709**	**4215.8709**	

13. Molecular Sieve (D-362)

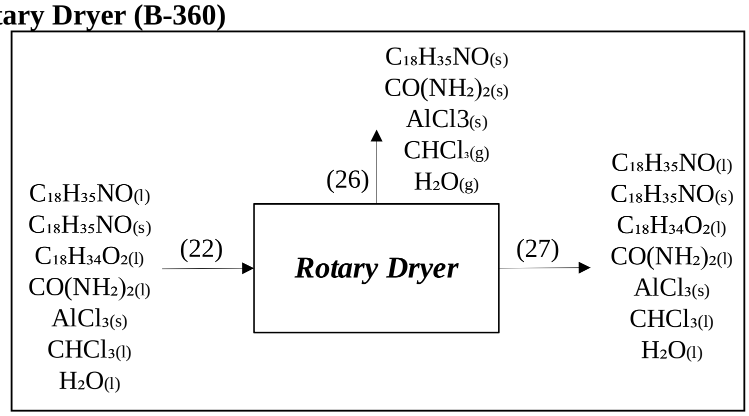


Neraca Massa Molecular Sieve (D-362)			
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**	
	23	**24**	**Terserap**
Udara Bebas	3319.170491		
Udara Kering		3236.941361	
$H_2O_{(l)}$			82.22913
Total	**3319.170491**	**3319.170491**	

14. Heater-2 (E-363)

Neraca Heater (E-363)		
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**
	24	**25**
Udara kering	3236.941	3236.941
Total	**3236.9414**	**3236.9414**

15. Rotary Dryer (B-360)



Aliran Masuk Rotary Dryer

Komponen	Massa (kg/jam)
$C_{18}H_{35}NO_{(l)}$	0.071
$C_{18}H_{35}NO_{(s)}$	3954.055
$C_{18}H_{34}O_{2(l)}$	10.446
$CO(NH_2)_{2(s)}$	0.449
$AlCl_{3(s)}$	0.422
$CHCl_{3(l)}$	1.978
$H_2O_{(l)}$	0.552
Total	**3967.973**

Aliran 26

Solid terbawa udara = 1% **(0,02-0,2%; Ludwig Vol.1; 4th ed; Hal-422)**

H_2O Teruapkan = 95%

CHCl3 Teruapkan = 95%

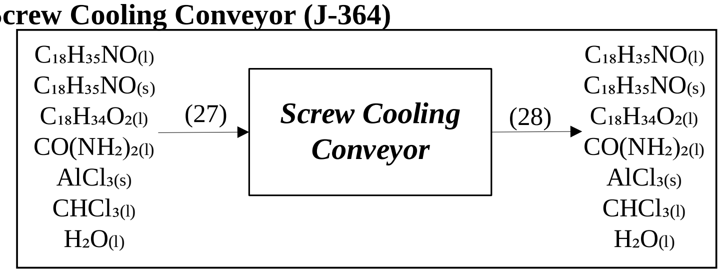
Solid terbawa udara

$C_{18}H_{35}NO_{(s)}$ = 1% x 3954.055 = 39.5405517 kg/jam

$CO(NH_2)_{2(s)}$ = 1% x 0.449 = 0.00449009 kg/jam
$AlCl_{3(s)}$ = 1% x 0.422 = 0.00422069 kg/jam
H_2O Teruapkan = 95% x 0.552 = 0.5244737 kg/jam
$CHCl_3$ Teruapkan = 95% x 1.9777 = 1.8788527 kg/jam

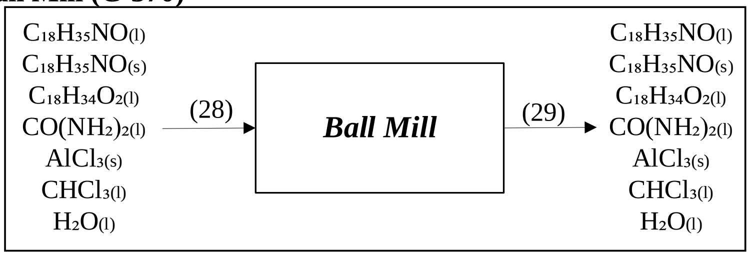
Neraca Massa Rotary Dryer (B-360)			
	Massa Masuk (kg/jam)	**Massa Keluar (kg/jam)**	
Komponen	**22**	**26**	**27**
$C_{18}H_{35}NO_{(l)}$	0.0712		0.071
$C_{18}H_{35}NO_{(s)}$	3954.0552	39.54055171	3914.5146
$C_{18}H_{34}O_{2(l)}$	10.4462		10.446
$CO(NH_2)_{2(s)}$	0.4490	0.004490092	0.4445
$AlCl_{3(s)}$	0.4221	0.004220687	0.4178
$CHCl_{3(l)}$	1.9777	1.879	0.099
$H_2O_{(l)}$	0.5521	0.5245	0.028
Total	**3967.9735**	**41.9526**	**3926.021**
Subtotal	**3967.9735**	**3967.9735**	

16. Screw Cooling Conveyor (J-364)



Neraca Massa Screw Cooling Conveyor (J-364)		
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**
	27	**28**
$C_{18}H_{35}NO_{(l)}$	0.0712	0.0712
$C_{18}H_{35}NO_{(s)}$	3914.5146	3914.5146
$C_{18}H_{34}O_{2(l)}$	10.4462	10.4462
$CO(NH_2)_{2(s)}$	0.4445	0.4445
$AlCl_{3(s)}$	0.4178	0.4178
$CHCl_{3(l)}$	0.0989	0.0989
$H_2O_{(l)}$	0.0276	0.0276
Subtotal	**3926.0209**	3926.0209
Total	**3926.0209**	**3926.0209**

17. Ball Mill (C-370)



Neraca Massa Ball Mill (C-370)		
Komponen	**Massa Masuk (kg/jam)**	**Massa Keluar (kg/jam)**
	28	**29**
$C_{18}H_{35}NO_{(l)}$	0.0712	0.0712
$C_{18}H_{35}NO_{(s)}$	3914.5146	3914.5146
$C_{18}H_{34}O_{2(l)}$	10.4462	10.4462
$CO(NH_2)_{2(s)}$	0.4445	0.4445
$AlCl_{3(s)}$	0.4178	0.4178
$CHCl_{3(l)}$	0.0989	0.0989
$H_2O_{(l)}$	0.0276	0.0276
Subtotal	**3926.0209**	**3926.0209**
Total	**3926.0209**	**3926.0209**

APPENDIX B
NERACA PANAS

Kapasitas Produksi	=	35000	Ton/hari
Waktu Operasi	=	330	hari/tahun
	=	24	jam/hari
Basis Perhitungan	=	1	Jam operasi
Satuan Massa	=	kg/jam	
Satuan Panas	=	Kkal/jam	
Suhu Referensi	=	25 = 298	K

Persamaan panas untuk kondisi aliran steady state

$$Q = \Delta H = H_2 - H_1$$

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

$$\Delta H = \Delta H = m \times Cp \times \Delta T = m \int_{Treff}^{T} Cp \times dT$$

Keterangan :

- H : panas (kkal)
- Cp : spesific heat (kkal/kmol.K)
- T_{reff} : Suhu refference (K)
- T : Suhu bahan (K)

Tabel Berat Molekul Senyawa

Komponen	Berat Molekul (kg/kmol)
$C_{18}H_{34}O_2$	282
$CO(NH_2)_2$	60
$C_{18}H_{35}NO$	281
$CHCl_3$	119
H_2O	18
CO_2	44
NH_3	17
$AlCl_3$	133

TABEL KONVERSI			
1 Kg	2.20462 lb	1 lb	0.45359 Kg
1 gr/cc	62.43 lb/cuft	1 lb/cuft	0.01602 gr/cc
1 ft	0.3048 m	1 m	3.28084 ft
1 cuft	0.028317 m^3	1 m^3	35.3147 cuft
1 ft	12 in	1 in	0.08333 ft
1 in	0.0254 m	1 m	39.3701 in
1 HP	550 lb.ft/dt	1 lb.ft/dt	0.00182 HP
1 cuft/m	7.480519 gpm	1 gpm	0.13368 cuft
1 lb/ft s	1488.164 cp	1 cp	0.00067 lb/ft s
1 atm	14.7 psi	1 lb/cuft	0.13368 lb/gal
	101.325 kpa		35.3147
	760.0021 mmHg	1 cuft	150.23 lb
1 kkal	3.966 btu	1 m3/jam	4.40287 gpm
1 ft^2	0.092903 m^2	1 mmHg	7.501 Kpa
1 kkal	4.184 kjoule	1 joile	0.23901 kal
1 grain	0.064799 gr	1 cuft	28.317 L
1 m^3	264.172 gal	1 mol/cu	0.0353 mol/L

Data Konstanta Cp Gas (Carl Yaws, 199 (joule/(mol K)

Persamaan yang dugunakan:

$$Cp = A + B \times T + C \times T^2 + D \times T^3 + E \times T^4$$

Komponen	A	B	C	D	E
$H_2O_{(g)}$	33.933	-0.0084	0.00003	-1.8E-08	3.7E-12
$CO_{2(g)}$	27.437	0.042315	-2E-05	4E-09	-2.9872E-13
$NH_{3(g)}$	33.573	-0.01259	8.89E-05	-7.18E-08	1.8569E-11
$CHCl_{3(g)}$	22.487	0.19823	-0.00022	1.16E-07	-2.4555E-11

Data Konstanta Cp Liquid (Carl Yaws, 199 (joule/(mol K)

Persamaan yang dugunakan:

$$Cp = A + B \times T + C \times T^2 + D \times T^3$$

Komponen	A	B	C	D
$C_{18}H_{34}O_{2(l)}$	278.686	2.5434	-0.00544	4.92E-06
$CO(NH_2)_{2(l)}$	965.507	-5.0993	0.01002	-6.38E-06
$CHCl_{3(l)}$	28.296	0.65897	-0.00204	2.59E-06
$H_2O_{(l)}$	92.053	-0.04	-0.00021	5.3E-07

Untuk estimasi kapasitas panas oleamida berupa cairan dapat dilihat berdasarkan kontribusi gugus atom pada suhu 293.15 K **Tabel 2-394 Perry 1997**

Tabel Nilai Kapasitas Panas Berdasarkan Konstribusi Gugus Atom

Ikatan	**ΔHf298 (kJ/mol**
-CH3	36.82
-CH2-	30.38
-COOH	79.91
-NH2	58.58
-Cl	38.38
-CH	20.92
-C =O	52.97
-OH	44.77

Oleamida (CH3(CH2)7CHCH(CH2)7CO(NH2))

Cp Cairan = 1(ΔCp-CH3)+14(ΔCp-CH2-)+2(ΔCp-CH-)+1(ΔCp-CO)+1(ΔCp-NH2)

= 615.53 j/mol.K

Data Konstanta Cp Soli (joule/(mol K)

Persamaan yang dugunakan:

$Cp = A + B \times T + C \times T^2$

Komponen	A	B	C
$CO(NH_2)_{2(s)}$	13.513	0.26827	2.13E-05
$AlCl_{(s)}$	12.954	0.41933	-0.00051

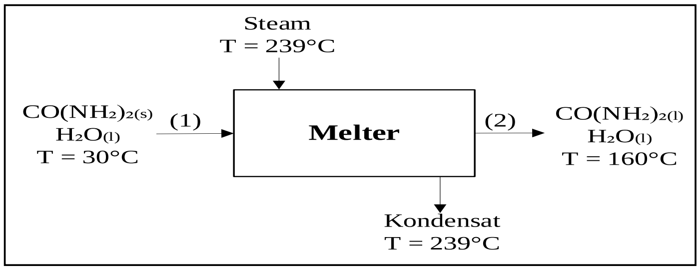
Untuk estimasi kapasitas panas oleamida berupa padatan dapat dilihat berdasarkan konstribusi elemen atom pada suhu 298.15 K pada Tabel 2-393 Perry 1997

Elemen Atom	ΔE (J/mol.K)
C	**10.89**
H	**7.56**
O	**13.42**
N	**18.74**

Cp Padatan (C18H35NO) = 18(ΔEC)+35(ΔEH)+1(ΔEO)+1(ΔEN)

= 492.78 j/mol.K

1. Melter (M-130)



Suhu Referensi (Treff)	=	25	°C =	298.15	K
Suhu Bahan Masuk	=	**30**	°C =	303.15	K
Suhu Bahan Keluar	=	160	°C =	433.15	K

Entalpi Bahan Masuk

Komponen	Massa (kg/jam)	n (kmol/jam)	∫CpdT	ΔH (Kkal/jam)
$CO(NH_2)_{2(s)}$	898.0184581	60	480.4619	6889.989005
$H_2O_{(l)}$	9.070893517	0.50393853	377.243932	45.4368432
Total				6935.425848

Entalpi Bahan Keluar

Komponen	Massa (kg/jam)	n (kmol/jam)	∫CpdT	ΔH (Kkal/jam)
$CO(NH_2)_{2(s)}$	898.0184581	60	15455.3474	221635.0012
$H_2O_{(l)}$	9.070893517	0.50393853	10236.2892	1232.901656
Total				222867.9029

Neraca Energi Total

Asumsi Q Loss = 0.05 Q Supply

ΔHin + + Q Supply = ΔHout + Qloss

6935.43 + Q Supply = 222868 + 0.05 Q Supply

0.95 Q Supply = 215932.477

Q Supply = 227297 kkal/jam

Q Loss = 11364.9 kkal/jam

Kebutuhan Steam

Panas di supply menggunakan saturated steam dengan suhu 239' (Ulrich, hal 426)

Dari Tabel E.1 Smith & Van Ness hal 719:

Hv = 2802 kJ/kg

Hl = 1032.85 kJ/kg

λ	=	Hs	-	hc
	=	2802.25	-	1033
	=	1769.4	kJ/kg	
	=	422.8967	kkal/kg	

$Q_{steam} = m_{steam} \times \lambda_{steam}$

Jadi jumlah Steam yang dibutuhkan sebesar:

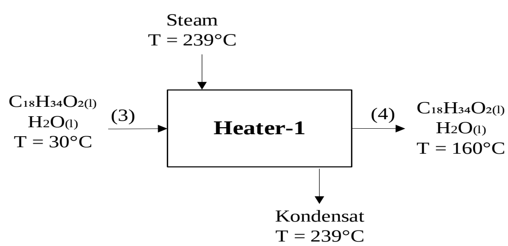
$$m_{steam} = \frac{Q_{suplay}}{\lambda_{steam}}$$

$$= \frac{227297.3 \text{ kkal/jam}}{422.8967 \text{ kJ/kg}}$$

$$= 537.4772 \text{ kg/jam}$$

NERACA PANAS MELTER (M-130)		
Komponen	**Q in (kkal/jam)**	**Q out (kkal/jam)**
	1	**2**
$CO(NH_2)_2$	6889.989005	221635.0012
H_2O	45.4368432	1232.901656
Qsupply	227297.3442	
Qloss		11364.86721
Total	**234232.7701**	**234232.7701**

2. Heater-1(E-122)



Suhu Referensi (Treff)	=	25	°C =	298.15	K
Suhu Bahan Masuk	=	**30**	°C =	303.15	K
Suhu Bahan Keluar	=	160	°C =	433.15	K

Entalpi Bahan Masuk

Komponen	Massa (kg/jam)	n (kmol/jam)	∫CpdT	ΔH (Kkal/jam)
$C_{18}H_{34}O_{2(l)}$	4220.686753	14.9669743	3429.27016	12267.16023
$H_2O_{(l)}$	42.63319953	2.36851108	377.243932	213.553163
Total				12480.7134

Entalpi Bahan Keluar

Komponen	Massa (kg/jam)	n (kmol/jam)	∫CpdT	ΔH (Kkal/jam)
$C_{18}H_{34}O_{2(l)}$	4220.686753	14.9669743	97554.2274	348970.2713
$H_2O_{(l)}$	42.63319953	2.36851108	10236.2892	5794.637784
Total				354764.9091

Neraca Energi Total

Asumsi Q Loss = 0.05 Q Supply

ΔHin + Q Supply = ΔHout + Qloss

12480.7 + Q Supply = 354765 + 0.05 Q Supply

0.95 Q Supply = 342284.196

Q Supply = 360299 kkal/jam

Q Loss = 18015 kkal/jam

Kebutuhan Steam

Panas di supply menggunakan saturated steam dengan suhu 239' (Ulrich, hal 426)

Dari Tabel E.1 Smith & Van Ness hal 719:

Hv = 2802 kJ/kg

Hl = 1032.85 kJ/kg

λ = Hs - hc

= 2802.25 - 1033

= 1769.4 kJ/kg

= 422.8967 kkal/kg

$Q_{steam} = m_{steam} \times \lambda_{steam}$

Jadi jumlah Steam yang dibutuhkan sebesar:

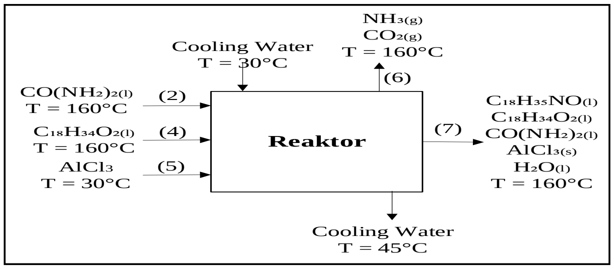
$$m_{steam} = \frac{Q_{suplay}}{\lambda_{steam}}$$

$$= \frac{360299.2 \text{ kkal/jam}}{422.8967 \text{ kJ/kg}}$$

= 851.979 kg/jam

NERACA PANAS HEATER (E-122)		
Komponen	Q in (kkal/jam)	Q out (kkal/jam)
	3	4
$C_{18}H_{34}O_{2(l)}$	12267.16023	348970.2713
H_2O	213.553163	5794.637784
Qsupply	360299.1533	
Qloss		18014.95767
Total	**372779.8667**	**372779.8667**

3. Reaktor (R-210)



Suhu Referensi (Treff)	=	25	°C =	298.15	K
Suhu Bahan Masuk	=	**160**	°C =	433.15	K
Suhu Bahan Keluar	=	160	°C =	433.15	K

Entalpi Bahan Masuk

Komponen	Massa (kg/jam)	n(kmol/jam)	∫CpdT	ΔH (kkal/jam)
$C_{18}H_{34}O_{2(l)}$	4220.686753	14.9669743	97554.22743	348970.2713
$CO(NH_2)_{2(l)}$	898.0184581	14.9669743	17997.33756	64379.94473
$AlCl_{3(s)}$	42.20686753	0.317344869	13137.53618	996.4459111
$H_2O_{(l)}$	51.70409304	2.872449614	10236.28922	7027.53944
Total				421374.2014

Entalpi Panas Reaksi

Reaksi yang terjadi dalam reaktor

$$C_{18}H_{34}O_2 + CO(NH_2)_2 \xrightarrow{AlCl_3} C_{18}H_{35}NO + CO_2 + NH_3$$

Panas Pembentukan Standar (ΔH°f298)

Untuk estimasi panas pembentukan standar reaktan dan produk dapat dilihat berdasarkan kontribusi gugus atom pada Tabel 2-161 Perry (2019).

Ikatan	ΔHf298 (kJ/mol
CO-(2N)	-76.54
N-(2H)(CO)	-20.64
C-(3H))C)	-42.26
C-(2H)(2C)	-20.63
Cd-(H)(C)	36.32
CO-(OH)(C)	-124.39
O-(H)(C)	-101.42
$CO\text{-}NH_2$	-101.42

$$\Delta HF298 = \sum_{i=1}^{n} ni + (\Delta Hf)i$$

Tabel ΔHF°298,15 Reaktan

Komponen	n (kmol/jam)	ΔHf (kJ/mol)	ΔHf (kkal/mol)	ΔHf (kkal/kmol)	ΔH°f (kkal/jam)
$C_{18}H_{34}O_{2(l)}$	14.9669743	-484.25	-115.739	-115739	-1732256
$CO(NH_2)_{2(l)}$	14.9669743	-97.18	-23.2266	-23226.6	-347632
Total					-2079887

Tabel ΔHF°298,15 Produ (Tabel 2-221 dan 2-222 Perry Edisi 7)

Komponen	n (kmol/jam)	ΔHf (kJ/mol)	ΔHf (kkal/mol)	ΔHf (kkal/kmol)	ΔH°f (kkal/jam)
$C_{18}H_{35}NO$	14.9669743	-380.5	-90.9417	-90941.7	-1361121.8
CO_2	14.9669743	-393.51357	-94.052	-94052	-1407673.9
NH_3	14.9669743	-4.5898	-1.09699	-1096.99	-16418.599
Total					-2785214.29

ΔHr°x = (H°f)Produk - (H°f)Reaktan
= -2785214.29 - -2079887
= -705327.13 kkal/jam

B. Entalpi Bahan Keluar

Tekanan = 1 atm
T in = 160 °C T = 135 K
= 433 K
Treff = 25 °C
= 298 K

Bahan Keluar Reaktor

Komponen	Massa Keluar (kg/jam)	n (kmol/jam)	∫CpdT (J/kmol)	ΔH (kkal/jam)
$C_{18}H_{35}NO(_l)$	3995.43379	14.2186256	83096.55	282389.754
$C_{18}H_{34}O_2(_l)$	211.0343377	0.74834872	97554.2274	17448.5136
$CO(NH_2)_2(_l)$	44.90092291	0.74834872	17997.3376	3218.99724
$AlCl_3(_s)$	42.20686753	0.31734487	13137.5362	996.445911
$CO_2(_g)$	625.6195258	14.2186256	5490.36657	18658.0943
$NH_3(_g)$	241.716635	14.2186256	4554.11261	15476.3915
$H_2O(_l)$	51.70409304	2.87244961	4591.09884	3151.93596
Total				341340.133

ΔH Reaksi = $\Delta H_{298,15K}$ + $(\Delta H_{Produk} - \Delta H_{Reaktan})$
= -705327.1348 + 316524.2401 - 20667.5108
ΔH Reaksi = -409470.41 kkal/jam

Karena ΔH Reaksi (-) maka reaksi yang terjadi eksoterm
sehingga memerlukan pendingin agar suhu tetap konstan

Neraca Panas Total Reaktor

Panas masuk = Panas Keluar

ΔH in + ΔHrx° = ΔH out + (Q serap - 5%Q serap)

95% Q = ΔH in - ΔH out + ΔHrx°

Q Serap = 515267.8674 Kkal/Jam

Q Loss = 25763.39337 Kkal/Jam

Kebutuhan Air Pendingin

Cooling water yang digunakan dengan suhu 30° C dan tekanan 1 atm
Diperkirakan suhu keuaran cooling water 45 °c (Ulrich App B 277)
Diperoleh Cp air = 4.187 kj/kg.I = 1.00072 kkal/kg.K

$$Q = m. Cp. \Delta T$$

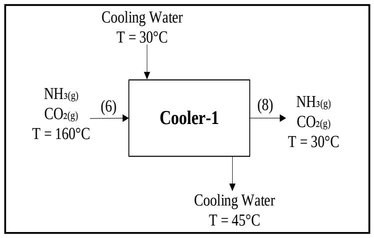
$$mcw = \frac{Qc}{cp. \Delta T}$$

$$= \frac{515267.8674}{1.000717 \ . \ (45\text{-}30)}$$

$$= 34326.58 \text{ kg/jam}$$

NERACA PANAS REAKTOR (R-210)					
Komponen	**Q in (kkal/jam)**			**Q out (kkal/jam)**	
	2	**4**	**5**	**6**	**7**
$C_{18}H_{35}NO$					282390
$C_{18}H_{34}O_2$		348970			17448.5
$CO(NH_2)_2$	64379.9				3219
$AlCl_3$			996.446		996.446
CO_2				18658.1	
NH_3				15476.4	
H_2O	1596.44	5431.1			3151.94
Qserap				515267.8674	
Qreaksi	409470.4054				
Qloss	25763.39337				
Total	**856608.0002**			**856608.0002**	

4. Cooler-1 (E-212)



A. Entalpi Bahan Masuk

Suhu Referensi (Treff)	=	25	°C =	298.15	K
Suhu Bahan Masuk	=	160	°C =	433.15	K
Suhu Bahan Keluar	=	30	°C =	303.15	K

Bahan Masuk Cooler

Komponen	Massa Masuk (kg/jam)	n (kmol/jam	CpdT (J/kmo	ΔH (kkal/jam
CO2(g)	625.6195258	14.2186256	5462.31942	18562.7807
NH3(g)	241.716635	14.2186256	5091.88596	17303.9245
Total				35866.7052

Bahan Keluar Cooler

Komponen	Massa Masuk (kg/jam)	n (kmol/jam	CpdT (J/kmo	ΔH (kkal/jam
CO2(g)	625.6195258	14.2186256	192.487812	654.137697
NH3(g)	241.716635	14.2186256	180.128302	612.135967
Total				1266.27366

Asumsi Q loss = 5% dari Q supply

Neraca Panas Total Cooler NH_3

ΔH bahan masuk = ΔH bahan keluar + Qloss + Q cw

35866.70522 = 1266.274 + 0.05 Q Supply + Qcw

Q cw = 36421.5069 Kkal/Jam

Q Loss = 1821.075345 Kkal/Jam

Cooling water yang digunakan dengan suhu 30° C dan tekanan 1 atm

Diperkirakan suhu keuaran cooling water 45 °c (Ulrich App B 277)

Diperoleh Cp air = 4.187 kj/kg.I = 1.00072 kkal/kg.K

$$Q = m. Cp. \Delta T$$

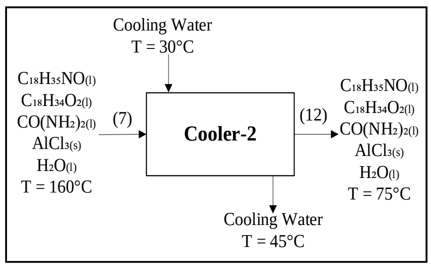
$$mcw = \frac{Qc}{cp. \Delta T}$$

$$= \frac{36421.5069}{1.000717 \;.\; (45\text{-}30)}$$

$$= 2426.361 \text{ kg/jam}$$

NERACA PANAS COOLER NH_3 (E-212)		
Komponen	**Q in (kkal/jam)**	**Q out (kkal/jam)**
	6	**8**
CO_2	18562.78074	654.1376974
NH_3	17303.92447	612.1359667
Q_{cw}		36421.5069
Q_{loss}	1821.075345	
Total	**37687.78056**	**37687.78056**

5. Cooler-2 (E-214)



Suhu Referensi (Treff)	=	25	°C =	298.15	K
Suhu Bahan Masuk	=	160	°C =	433.15	K
Suhu Bahan Keluar	=	75	°C =	348.15	K

Bahan Masuk Cooler

Komponen	Massa Masuk (kg/jam)	n (kmol/jam	CpdT (J/kmo	ΔH (kkal/jam
$C_{18}H_{35}NO$	3955.479452	14.0764393	83096.55	279565.857
$C_{18}H_{34}O_2$	208.9239943	0.74086523	97554.2274	17274.0284
$CO(NH_2)_2$	0.449009229	0.00748349	17997.3376	32.1899724
$AlCl_3$	0.422068675	0.00317345	13137.5362	9.96445911
H_2O	51.70409304	2.87244961	10236.2892	7027.53944
Total				303909.579

Bahan Keluar Cooler

Komponen	Massa Masuk (kg/jam	n (kmol/jam	CpdT (J/kmo	ΔH (kJ/jam)
$C_{18}H_{35}NO$	3955.479452	14.0764393	30776.5	103542.91
$C_{18}H_{34}O_2$	208.9239943	0.74086523	34950.1126	6188.65277
$CO(NH_2)_2$	0.449009229	0.00748349	7476.18357	13.3718747
$AlCl_3$	0.422068675	0.00317345	4754.64168	3.60626468
H_2O	51.70409304	2.87244961	3757.29126	2579.50044
Total				112328.041

Asumsi Q loss = 5% dari Q supply

Neraca Panas Total Cooler

ΔH bahan masuk = ΔH bahan keluar + Qloss + Q cw

303909.5791 = 112328 + 0.05 Q Serap + Qcw

Q cw = 201664.7766 Kkal/Jam

Q Loss = 10083.23883 Kkal/Jam

Cooling water yang digunakan dengan suhu 30 C dan tekanan 1 atm

Diperkirakan suhu keuaran cooling water 45 c (Ulrich App B 277)

Diperoleh Cp air = 4.187 kj/kg.K = 1.00072 kkal/kg.K

$$Q = m.\ Cp.\ \Delta T$$

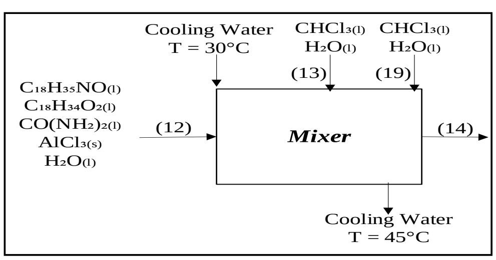
$$mcw = \frac{Qc}{cp.\ \Delta T}$$

$$= \frac{201664.7766}{1.000717\ .\ (45\text{-}30)}$$

$$= 13434.69 \text{ kg/jam}$$

NERACA PANAS COOLER (E-214)		
Komponen	**Q in (kkal/jam)**	**Q out (kkal/jam)**
	7	**12**
$C_{18}H_{35}NO$	279565.8568	103542.9099
$C_{18}H_{34}O_2$	17274.02843	6188.652765
$CO(NH_2)_2$	32.18997236	13.37187469
$AlCl_3$	9.964459111	3.606264676
H_2O	7027.53944	2579.500438
Qcw	-	201664.7766
Qloss	10083.23883	
Total	**313992.8179**	**313992.8179**

6. Mixer (M-310)



A. Entalpi Bahan Masuk

Suhu Referensi (Treff)	=	25	°C =	298.15	K
Suhu Bahan Masuk	=	75	°C =	348.15	K
Suhu Bahan Keluar	=	30	°C =	303.15	K

Bahan Masuk Mixer

Komponen	Massa Masuk (kg/jam	n (kmol/jam	CpdT (J/kmol	ΔH (kkal/jam
$C_{18}H_{35}NO$	3955.479452	14.0764393	30776.5	103542.91
$C_{18}H_{34}O_2$	208.9239943	0.74086523	34950.1126	6188.65277
$CO(NH_2)_2$	0.449009229	0.00748349	7476.18357	13.3718747
$AlCl_3$	0.422068675	0.00317345	4754.64168	3.60626468
$CHCl_3$	37.95662101	0.3189632	5810.16586	442.932386
$CHCl_3$	159.8173516	1.34300295	5810.16586	1864.97847
H_2O	51.18705211	2.84372512	3757.29126	2553.70543
H_2O	0.75913242	0.04217402	3757.29126	37.8728703
H_2O	3.261578604	0.18119881	3757.29126	162.719099
Total				**114810.749**

Bahan Keluar Mixer

Komponen	Massa Masuk (kg/jam)	n (kmol/jam	CpdT (J/kmo	ΔH (kJ/jam)
$C_{18}H_{35}NO$	3955.479452	14.0764393	3077.65	10354.291
$C_{18}H_{34}O_2$	208.9239943	0.74086523	34950.1126	6188.65277
$CO(NH_2)_2$	0.449009229	0.00748349	823.719875	1.47330237
$AlCl_3$	0.422068675	0.00317345	464.608854	0.35239301
$CHCl_3$	197.7739726	1.66196616	564.149304	224.091073
H_2O	55.20776314	3.06709795	377.243932	276.540175
Total				**17045.4007**

Asumsi Q loss = 5% dari Q supply

Neraca Panas Total Mixer

ΔH bahan masuk = ΔH bahan keluar + Qloss + Q cw

114810.7491 = 17045.4 + 0.05 Q Supply + Qcw

Q cw = 102910.893 Kkal/Jam

Q Loss = 5145.544651 Kkal/Jam

Cooling water yang digunakan dengan suhu 30 °C dan tekanan 1 atm

Diperkirakan suhu keuaran cooling water 45 °c (Ulrich App B 277)

Diperoleh Cp air = 4.187 kj/kg.K = 1.00072 kkal/kg.K

$$Q = m.\ Cp.\ \Delta T$$

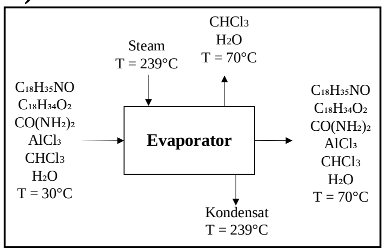
$$mcw = \frac{Qc}{cp.\ \Delta T}$$

$$= \frac{102910.893}{1.000717\ .\ (45\text{-}30)}$$

$$= 6855.81 \text{ kg/jam}$$

NERACA PANAS MIXER (M-310)				
Komponen	**Q in (kkal/jam)**			**Q out (kkal/jam)**
	12	**13**	**19**	**14**
$C_{18}H_{35}NO$	103542.9099			10354.29099
$C_{18}H_{34}O_2$	6188.652765			6188.652765
$CO(NH_2)_2$	13.37187469			1.473302367
$AlCl_3$	3.606264676			0.352393011
$CHCl_3$		442.9323862	1864.97847	224.091073
H_2O	2553.705434	37.87287031	162.719099	276.5401746
Qcw	-			102910.893
Qloss	5145.544651			
Total	**119956.2937**			**119956.2937**

7. Evaporator (V-330)



A. Entalpi Bahan Masuk

Suhu Referensi (Treff) = 25 °C = 298 K

Suhu Bahan Masuk = 30 °C = 303 K

Enthalpy bahan masuk :

Komponen	**Massa Masuk (kg/jam)**	**n (kmol/jam**
$C_{18}H_{35}NO$	3955.479452	14.0764393
$C_{18}H_{34}O_2$	208.9239943	0.74086523
$CHCl_3$	197.7739726	1.66196616
H_2O	55.20776314	3.06709795

Menentukan Suhu Keluar (T out Evaporator)

1. Menentukan Kondisi Puncak Menara

Perhitungan Dew Point

Trial Suhu dan Tekanan, trial dianggap benar jika xi=1

P = 1 atm = 760 mmHg

T = 57.4 C = 330.55 K

dimana xi= yi/ki

ln Pi = A-B/ (C+T)

Data Physical Properties (MSDS)

Komponen	Rumus Molekul	BM (kg/kmol)	Titik Didih (°C)
Oleamida	$C_{18}H_{35}NO$	281	320
Asam Oleat	$C_{18}H_{34}O_2$	282	360
Kloroform	$CHCl_3$	119	61.2
Air	H_2O	18	100

Konstanta Antoine (Coulson)

Komponen	A	B	C
Oleamida	16.9553	4450.4	-135.6
Asam Oleat	18.2445	5884.49	-127.26
Kloroform	15.9732	2696.79	-46.16
Air	19.3036	3816.44	-46.13

Tabel Komponen Uap Keluaran Atas Evaporator

Komponen	m	n	yi	Psat	Ki	xi
	(kg/jam)	(kmol/jam)		mmHG		
CHCL3	158.2192	1.66197	0.35	658.841	0.86689638	0.4054
H2O	55.20776	3.0671	0.65	359.702	1.0881914	0.596
Total	**202.3854**	**4.72906**	**1**			**1.00**

2. Menentukan Kondisi Kondesat

Kondisi kondesat keluar (*bubble point)*

Trial Kondisi Pawah

P = 1 atm = 760 mmHg

T = 70.1 °C = 343.25 K

T dicari dengan car trial dan eror dan dianggap benar jika nilai ∑xi*ki)= 1

dimana yi=xi.ki

ln Pi = A-B/ (C+T)

Tabel komponen Kondesat Keluar Evaporator

Komponen	m	n	xi	Psat	Ki	yi
	(kg/jam)	(kmol/jam)		mmHG		
$C_{18}H_{35}NO$	3955.4795	14.0764	42.3	0.011368	1.4958E-05	0.000633
$C_{18}H_{34}O_2$	208.92399	0.74087	2.23	0.000123	1.6242E-07	3.62E-07
$CHCl_3$	39.554795	0.33239	0.35	988.165	1.30021712	0.456944
H_2O	11.041553	0.61342	0.65	638.3096	0.83988109	0.544716
Total	**4215**	**0.94581**	**1**			**1.00**

Panas Masuk Evaporator

Tin = 30 °C = 303.15 K
Tref = 25 °C = 298.15 K

Komponen	Massa Masuk (kg/jam)	n (kmol/jam	CpDT	Qin (kkal/jam)
$C_{18}H_{35}NO$	3955.479452	14.0764393	3077.65	10354.291
$C_{18}H_{34}O_2$	208.9239943	0.74086523	3429.27016	607.224432
$CO(NH_2)_2$	0.449009229	0.00748349	823.719875	1.47330237
$AlCl_3$	0.422068675	0.00317345	464.608854	0.35239301
$CHCl_3$	197.7739726	1.66196616	564.149304	224.091073
H_2O	55.20776314	3.06709795	377.243932	276.540175
Total				**11463.97237**

Panas Laten Penguapan Komponen

Komponen	TC	Tb	A	n	ΔHv (Kj/mol)
$CHCl_3$	536.4	334.33	42.953	0.375	31.177
H_2O	647.13	373.15	52.053	0.321	42.296

Sumber: Yaws C,L, 1999. Tabel 5.1-5.2)

Menghitung entalpi panas penguapan ΔHv menggunakan Persamaan Watson

$$\frac{\Delta H2}{\Delta H1} = \left(\frac{1-Tr_2}{1-Tr_1}\right)^{0.4}$$ Pers 4.13 Smith Van Ness, hal 134 Chapter 4

$$\Delta H2 = \Delta H1 \left(\frac{1-Tr_2}{1-Tr_1}\right)^{0.38}$$

CHCL3

$$\Delta H2 = \Delta H1 \left(\frac{1-Tr_2}{1-Tr_1}\right)^{0.38}$$

Tr2 = T2/Tc

$= \frac{330.55}{536.4}$ K (T Dew)

= 0.6162

Tr1 = T1/Tc

$= \frac{334.33}{536.4}$ K (T Didih Komponen)

= 0.6233

$$\Delta H2 = 31.177 \times \left(\frac{1-(\frac{333.95}{536.4})}{1-(\frac{334.33}{536.4})}\right)^{0.38}$$

= 31.39735 kJ/kmol

ΔHv = 1.661966 **x** 31.3973 = 52.1813 kJ/jam

H2O

$$\Delta H2 = \Delta H1 \left(\frac{1 - Tr_2}{1 - Tr_1}\right)^{0.38}$$

Tr2 = T2/Tc

$= \dfrac{330.55}{647.13}$ K (T Dew)

= 0.5108

Tr1 = T1/Tc

$= \dfrac{373.15}{647.13}$ K (T Didih Komponen)

= 0.5766

$$\Delta H2 = 42.296 \times \left(\frac{1 - (\frac{333.95}{536.4})}{1 - (\frac{334.33}{536.4})}\right)^{0.38}$$

= 44.68377 kJ/kmol

ΔHv = 3.067098 **x** 44.6838 = 137.05 kJ/jam

Q2 = Q CHCL3 + Q H2O

= 52.18133 + 137.05

= 189.2308 kJ/jam

= 45.22726 kkal/jam

Pana Keluaran Bawah Evaporator

Tout = 70 °C = 343.25 K

Tref = 25 °C = 298.15 K

Komponen	Massa (kg/jam)	n (kmol/jam	CpDT	Q (kkal/jam)
$C_{18}H_{35}NO$	3955.479452	14.0764393	27760.403	93395.7047
$C_{18}H_{34}O_2$	208.9239943	0.74086523	31462.3863	5571.07744
$CO(NH_2)_2$	0.449009229	0.00748349	16344.3193	29.2333899
$AlCl_3$	0.422068675	0.00317345	4279.53156	3.24590674
$CHCl_3$	39.55479452	0.33239323	5222.79756	414.919349
H_2O	11.04155263	0.61341959	3389.66699	496.961792
Total				**99911.14262**

Neraca Panas Total Evaporator

ΔH bahan masuk + Q Supply = ΔH bahan keluar + Q loss

11463.97237 + Q supply = 99956.37 + 0.05 Q Supply

Q supply = 93149.89212 Kkal/Jam

Q Loss = 4657.494606 Kkal/Jam

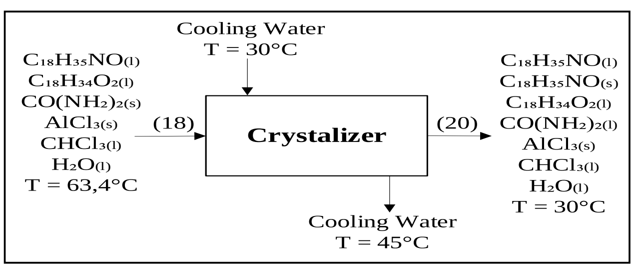
Panas disuply dengan saturated steam suhu 239°C (Yaws, hal 426)
Dari tabel F.1 Smith & Van Nesh hal 719

Hv = 2802.3 kj/kg
Hl = 1032.85 kj/kg
λ = 1769.45 kj/kg
= 422.9087 kkal/kg

Massa Steam = $\frac{Qs}{\lambda}$ = $\frac{93149.8921}{422.9087}$ = 220.26 kg/jam

NERACA PANAS EVAPORATOR (V-330)			
Komponen	**Q in (kkal/jam)**	**Q out (kkal/jam)**	
	16	18	17
$C_{18}H_{35}NO$	10354.29099	93395.70474	
$C_{18}H_{34}O_2$	607.2244316	5571.077443	
$CO(NH_2)_2$	1.473302367	29.23338992	
$AlCl_3$	0.352393011	3.245906739	
$CHCl_3$	224.091073	414.919349	12.4716368
H_2O	276.5401746	496.9617917	32.7556197
Qsupply	93149.89212	-	
Qloss		4657.494606	
Subtotal	104613.8645	104568.6372	45.2272565
Total	**104613.8645**	**104613.8645**	

8. Crystalizer (X-340)



Panas Masuk Crystalizer

T in = 63.4 °C = 336.55 K
Tref = 25 °C = 298.15 K

Komponen	Massa (kg/jam)	n (kmol/jam	CpDT	Q (kkal/jam)
$C_{18}H_{35}NO$	3955.479452	14.0764393	23636.352	79520.9548
$C_{18}H_{34}O_2$	208.9239943	0.74086523	26714.9402	4730.44222
$CO(NH_2)_2$	0.449009229	0.00748349	13731.8342	24.5607085

$AlCl_3$	0.422068675	0.00317345	3632.60359	2.75522971
$CHCl_3$	39.55479452	0.33239323	4426.51975	351.659943
H_2O	11.04155263	0.61341959	2887.10495	423.280769
Total				**85053.65369**

Panas Keluar Crystalizer

T out = 40 °C = 313.15 K

Tref = 25 °C = 298.15 K

Komponen	Massa (kg/jam)	n (kmol/jam	CpDT	Q (kkal/jam)
$C_{18}H_{35}NO_{(l)}$	1.4242807	0.00506861	9232.95	11.1850538
$C_{18}H_{35}NO_{(s)}$	3954.055171	14.0713707	9232.95	31051.6879
$C_{18}H_{34}O_2$	208.9239943	0.74086523	5147.7224	911.512555
$CO(NH_2)_2$	0.449009229	0.00748349	5147.7224	9.20719753
$AlCl_3$	0.422068675	0.00317345	1401.95601	1.06334499
$CHCl_3$	39.55479452	0.33239323	1702.96249	135.289963
H_2O	11.04155263	0.61341959	1130.21113	165.701159
Total				**32285.64719**

Kebutuhan Air Pendingin

Panas masuk = Panas Keluar

Q1 = Q2 + Qcw

= 85053.7 - 32285.6

= 52768.0065 kkal/jam

Cooling water yang digunakan dengan suhu 30°C, dengan keluaran 45°C

Cp air = 4.187 kJ/kg.K = 1.00072 kkal/kg.K

$Q = m. Cp. \Delta T$

$m = \dfrac{Q}{Cp.\Delta T}$

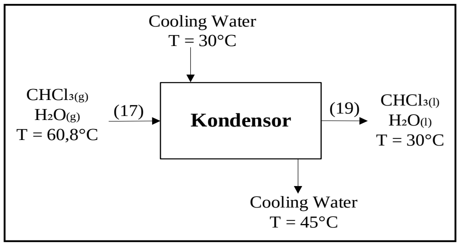
$= \dfrac{52768.00649}{1.000717 \; . \; 15}$

= 3515.346536 kg/jam

Komponen	Q in (kkal/jam)	Q out (kkal/jam)
	NERACA PANAS Crystalizer	
	18	**20**
$C_{18}H_{35}NO_{(l)}$	79520.95481	11.1850538
$C_{18}H_{35}NO_{(s)}$	-	31051.68792
$C_{18}H_{34}O_2$	4730.442222	911.5125551
$CO(NH_2)_2$	24.56070854	9.207197527
$AlCl_3$	2.755229708	1.063344994

$CHCl_3$	351.6599432	135.2899629
H_2O	423.2807692	165.7011586
Qcw	-	52768.00649
Total	**85053.65369**	**85053.65369**

9. Kondensor (E-331)



Panas Masuk Kondensor

Tin = 70 °C = 343.15 K

T ref = 25 °C = 298.15 K

Komponen	Massa (kg/jam	n(kmol)	∫CpdT	Q (kkal/jam)
$CHCl_3$	158.2191781	1.66196616	5210.85526	2069.853033
H_2O	55.20776314	3.06709795	3382.16552	2479.309973
Total				**4549.163006**

Panas Keluar Kondensor

Tin = 30 °C = 303.15 K

T ref = 25 °C = 298.15 K

Komponen	Massa (kg/jam	n(kmol)	∫CpdT	Q (kkal/jam)
$CHCl_3$	158.2191781	1.66196616	564.149304	224.091073
H_2O	55.20776314	3.06709795	377.243932	276.5401746
Total				**500.6312477**

Kebutuhan Air Pendingin

Panas masuk = Panas Keluar

Qc = Q1 - Q2

= 4549.163006 - 500.631248

= 4048.53176 kj/jam

Cooling water yang digunakan dengan suhu 30°C, dengan keluaran 45°C

Cp air = 4.187 kJ/kg.K 1.00072 kkal/kg.K

Q = m. Cp. ΔT

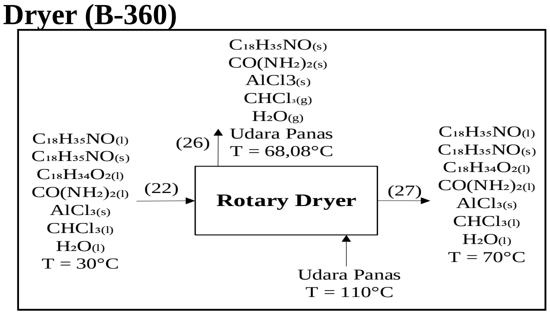
$$m = \frac{Q}{Cp.\Delta T}$$

$$= \frac{4048.531759}{1.000717 \,.\, 15}$$

= 269.7087315 kg/jam

Neraca Panas Kondensor (E-331)		
Komponen	**Qin (kkal/jam)**	**Qout (kkal/jam)**
	17	**19**
$CHCl_3$	2069.853033	224.091073
H_2O	2479.309973	276.5401746
Qcw		4048.531759
Total	**4549.163006**	**4549.163006**

10. Rotary Dryer (B-360)



Kondisi Operasi

Suhu bahan masuk dari centrifuge	=	30	°C	=	303.15	K
Suhu bahan keluar dari rotary dryer	=	70	°C	=	343.15	K
Suhu udara masuk	=	110	°C	=	383.15	K
Suhu udara keluar	=	68.8	°C	=	341.95	K

Menentukan % Relative Humidity (Hr)

Udara pada 30 oC dan P = 1 atm, mengandung uap air dengan tekanan parsial (PA = 2,97 kPa). Dari steam table (App. A.2-9 Geankoplis, 2003) untuk suhu 30 oC diperoleh tekanan uap (PAS) sebesar 4,246 kPa

$$Hr = 100 \times \frac{Pa}{Pas}$$

$$= 100 \times \frac{2.97}{4.246}$$

$$= 69.9$$

$$= 0.7$$

Berdasarkan humidity chart (Fig. 9.3-2, Geankoplis, 2003: 568) diperoleh

H = 0.019 kg uap air/kg udara kering

Asumsi bahwa humidity (H) tidak berubah saat udara dipanaskan sehingga

H1 = 0.019 kg uap air/kg udara kering

Penentuan Wet Bulb (Tw)

$$H_w - H_G = \frac{h_G}{K_G . M_B . \lambda_W}(T_G - T_W)$$

(Geankoplis, pers 9.3-18, hal 532)

$\frac{h_G}{K_G.M_B}$ = 0.26 (Table 8-1 Badger Banchero pengukuran wet bulb sistem udara-air)

Tw didapatkan dengan cara trial

dipilih tw = 135 °F = 56.9446 °C = 330.095 K

H_W = 0.0414 lb air/lb udara kering (Smith Tabel F.1 hal 719)

λ_W = 1108.4798 btu/lbm

$$0.0414 - 0.019 = 0.26 \times \frac{1}{1108} \times (230 - 134.5)$$

$$0.0224 = 0.0224$$

Sehingga Tw = 56.9446 °C

Menetukan suhu udara keluar udara rotary dryer

Menggunakan persamaan Number of Tranfer Units (NTU)

Untuk design Rotary Dryer, Number of Transfer Units

berkisar antara 1,5 - 2 (Banchero,hal. 508)

Sehingga, diambil NTU sebe = 1.5

Diketahui

$$NTU = \ln \frac{T_{G2} - T_W}{T_{G1} \quad T_W}$$

$$2 = \ln \frac{230 - 135}{T_{G1} - 135}$$

$$4.48 = \left(\frac{95.49979815}{t_{G1} - 134.5} \right)$$

t_{G1} - 134.5002 = 21.3089

t_{G2} = 155.809087 °F

= 68.7828262 °C

Sehingga TG1 adalah 68.8 °C

Menghitung panas masuk rotary dryer

Tin = 30 °C = 303.15 K

Treff = 20 °C = 293.15 K

Komponen	Massa (kg/jam)	n (kmol/jam	CpDT	Q (kkal/jam)
$C_{18}H_{35}NO_{(l)}$	0.071214035	0.00025343	6155.3	0.37283513
$C_{18}H_{35}NO_{(s)}$	3954.055171	14.0713707	4927.8	16572.873
$C_{18}H_{34}O_{2(l)}$	10.44619971	0.03704326	6843.15516	60.5862298
$CO(NH_2)_{2(s)}$	0.449009229	0.00748349	953.899744	1.70614161

$AlCl_{3(s)}$	0.422068675	0.00317345	926.33788	0.70260175
$CHCl_{3(l)}$	1.977739726	0.01661966	1124.89724	4.46831055
$H_2O_{(l)}$	0.552077631	0.03067098	755.084759	5.53517906
Total				**16646.2443**

Menghitung panas keluar rotary dryer

Menuju Cyclone

Tout = 69 °C = 341.933 K

T ref = 20 °C = 293.15 K

Komponen	Massa (kg/jam)	n (kmol/jam	CpDT	Q (kkal/jam)
$C_{18}H_{35}NO_{(s)}$	39.54055171	0.14071371	24039.2011	808.471582
$CO(NH_2)_{2(s)}$	0.004490092	7.4835E-05	4919.76152	0.08799468
$AlCl_{3(s)}$	0.004220687	3.1734E-05	4613.82406	0.03499458
$H_2O_{(l)}$	0.52447375	0.02913743	3668.70266	25.5488931
Total				**808.594572**

Menuju Cooling Conveyor

Tout = 70 °C = 343.15 K

T ref = 20 °C = 293.15 K

Komponen	Massa (kg/jam)	n (kmol/jam	CpDT	Q (kkal/jam)
$C_{18}H_{35}NO_{(l)}$	0.071214035	0.00025343	30776.5	1.86417563
$C_{18}H_{35}NO_{(s)}$	3914.51462	13.930657	24639	82035.7213
$C_{18}H_{34}O_{2(l)}$	10.44619971	0.03704326	34805.2311	308.149922
$CO(NH_2)_{2(s)}$	0.444519137	0.00740865	5051.09951	8.9440344
$AlCl_{3(s)}$	0.417847989	0.00314171	4731.58135	3.55288631
$CHCl_{3(l)}$	0.098886986	0.00083098	5771.60319	1.14629651
$H_2O_{(l)}$	0.027603882	0.00153355	3760.00634	1.37814385
Total				**82360.7568**

Menghitung panas penguapan H_2O

Tout = 70 = 343.15 K

T ref = 20 = 293.15 K

Komponen	Massa (kg/jam)	n (kmol/jam	CpDT	Q (kkal/jam)
$H_2O_{(l)}$	0.496869868	0.02760388	3760.00634	24.8065893
Total				**24.8065893**

λ H_2O = 9717 kkal/kmol

n λ = 0.027604 x 9717 kkal/kmol

= 268.2269

H_2O nλ = 24.80659 + 268.227
= 293.0335 kkal/jam

Menghitung panas udara masuk dan keluar Rotary D (Qgi dan Qgo)
Neraca Energi Total
Q in = Q out
Q in + Qgi = Q out + Qgo
16646.2 + Qgi = 83462.4 + Qgo

Tabel Kapasitas Panas (Cp) Udara = A + BT + CT2 + DT3 + ET4

Komponen	A	B	C	D	E
N_2	29.342	-0.00354	1E-05	-4.3E-09	2.6E-11
O_2	29.529	-0.0089	3.8E-05	-3.3E-08	8.9E-12

Panas Udara Masuk (Qgi)
Tg2 = 110 °C = 383.15 K
Tref = 25 °C = 298.15 K

Komponen	n (kmol)	∫CpdT	Hout (kkal/jam)	
N_2	n	2464.67	589.069608	n
O_2	n	2514.37	600.949582	n
Total			**1190.01919**	**n**

Panas Udara Keluar (Qgo)
Tg2 = 68.78283 °C = 341.933 K
Tref = 25 °C = 298.15 K

Komponen	n (kmol)	∫CpdT	Hout (kkal/jam)	
N_2	n	1261.97	301.618565	n
O_2	n	1288.01	307.840664	n
Total			**609.459228**	**n**

Neraca Energi Total
Q in = Q out
Q in + Qgi = Q out + Qgo
16646.2 + Qgi = 83462.4 + Qgo
16646.2 + 1190.019 n = 83462.4 + 609.459 n
580.56 n = 66816.1
n = 115.089 kmol/jam

Sehingga
Qgi = 1190.019 x n
= 1190.019 x 115.089

	=	136958.3	kkal/jam	
Qgo	=	609.4592	x	n
	=	609.4592	x	115.089
	=	70142.13	kkal/jam	

Kebutuhan Panas Udara

Komponen Udara

O_2	=	0.21	x	115.089129
	=	24.1687172	Kmol/Jam	
	=	773.398949	Kg/Jam	
N_2	=	0.79	x	115.089129
	=	90.9204122	Kmol/Jam	
	=	2545.77154	Kg/Jam	
Berat udara	=	3319.17049	Kg/Jam	

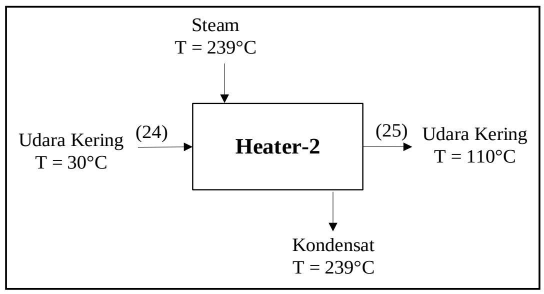
Perhitungan Enthalpy Komponen Udara

Udara Masuk	T	=	110	°C	=	383	K
ΔH Udara Masuk		=	1190.01919	x	115.089129		
		=	136958.273	Kkal/Jam			
ΔH	O_2	=	1190.01919	x	24.1687172		
		=	28761.2372	Kkal/Jam			
ΔH	N_2	=	136958.273	-	28761.2372		
		=	108197.035	Kkal/Jam			
Udara Keluar	T	=	68.8	°C	=	342	K
ΔH Udara Keluar		=	609.459228	x	115.089129		
		=	70142.132	Kkal/Jam			
ΔH	O_2	=	609.459228	x	24.1687172		
		=	14729.8477	Kkal/Jam			
ΔH	N_2	=	70142.132	-	14729.8477		
		=	55412.2843	Kkal/Jam			

Neraca Panas Rotary Dryer			
Komponen	**Q in (kkal/jam)**	**Q out (kkal/jam)**	
	22	27	26
$C_{18}H_{35}NO_{(l)}$	0.372835127	1.864175633	
$C_{18}H_{35}NO_{(s)}$	16572.873	82035.72133	808.471582
$C_{18}H_{34}O_{2(l)}$	60.58622981	308.1499217	
$CO(NH_2)_{2(s)}$	1.706141605	8.9440344	8.9440344
$AlCl_{3(s)}$	0.702601751	3.552886305	0.03499458

$CHCl_{3(l)}$	4.46831055	1.146296508	
$H_2O_{(l)}$	5.535179061	1.378143852	
H_2O λn			293.033507
Qgi	136958.2726	-	-
Qgo	-	70142.13198	
Subtotal	**153604.5168**	**82360.75679**	**1110.48412**
Total	**153604.5168**	**153604.5168**	

11. Heater-2 (E-362)



Udara yang di butuh kan RD = 3319.17049
Dimana denfan komposisi udara 79% N2 dan 21%O2
N2 = 773.3989 kb/jam = 27.6214 kmol/jam
O2 = 2545.772 kb/jam = 79.5554 kmol/jam

Udara Masuk
Tin = 30 °C = 303 K
Tref = 20 °C = 293 K

Komponen	n (kmol)	∫CpdT	H (kkal/jam)
N_2	27.62139	279.498	1845.154853
O_2	79.55536	290.14	5516.772199
Total			7361.927053

Udara Keluar
Tout = 110 ℃ = 383 K
Tref = 20 ℃ = 293 K

Komponen	n (kmol)	∫CpdT	H (kkal/jam)
N_2	27.62139	2610.98	17236.84638
O_2	79.55536	2661.63	50608.69942
Total			**67845.54581**

Neraca Panas Total
Qsteam = Qou - Qin
= 67845.55 - 7361.93

= 60483.62

Panas disuply dengan saturated steam suhu 148°C (Yaws, hal 426)

Dari tabel F.1 Smith & Van Nesh hal 719

Hv = 2743 kj/kg

Hl = 623.5 kj/kg

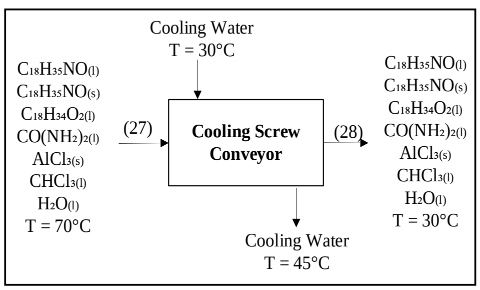
λ = 2119.5 kj/kg

= 506.5727 kkal/kg

Massa Steam = $\frac{Qs}{\lambda}$ = $\frac{60483.6188}{506.572658}$ = 119.398 kg/jam

Neraca Panas Heater (E-362)		
Komponen	Qin (kkal/jam)	Qout (kkal/jam)
	24	25
N_2	1845.154853	17236.84638
O_2	5516.772199	50608.69942
Qsteam	60483.61876	
Total	**67845.54581**	**67845.54581**

12. Cooling Screw Conveyor (J-364)



Panas yang Masuk

Tin = 70 °C = 343 K

Treff = 20 °C = 293 K

Komponen	Massa (kg/jam)	n (kmol/jam	CpDT	Q (kkal/jam)
$C_{18}H_{35}NO_{(l)}$	0.071214035	0.00025343	30776.5	1.86417563
$C_{18}H_{35}NO_{(s)}$	3914.51462	13.930657	24639	82035.7213
$C_{18}H_{34}O_{2(l)}$	10.44619971	0.03704326	34805.2311	308.149922
$CO(NH_2)_{2(s)}$	0.444519137	0.00740865	5051.09951	8.9440344
$AlCl_{3(s)}$	0.417847989	0.00314171	4731.58135	3.55288631
$CHCl_{3(l)}$	0.098886986	0.00083098	5771.60319	1.14629651
$H_2O_{(l)}$	0.027603882	0.00153355	3760.00634	1.37814385
Total				**82360.7568**

Panas yang Keluar

Tin = 30 °C = 303 K
Treff = 20 °C = 293 K

Komponen	Massa (kg/jam)	n (kmol/jam	CpDT	Q (kkal/jam)
$C_{18}H_{35}NO_{(l)}$	0.071214035	0.00025343	30776.5	1.86417563
$C_{18}H_{35}NO_{(s)}$	3914.51462	13.930657	24639	82035.7213
$C_{18}H_{34}O_{2(l)}$	10.44619971	0.03704326	6843.15516	60.5862298
$CO(NH_2)_{2(s)}$	0.444519137	0.00740865	953.899744	1.68908019
$AlCl_{3(s)}$	0.417847989	0.00314171	926.33788	0.69557573
$CHCl_{3(l)}$	0.098886986	0.00083098	1124.89724	0.22341553
$H_2O_{(l)}$	0.027603882	0.00153355	755.084759	0.27675895
Total				**82101.0566**

Neraca Panas Total

Panas masuk = Panas Keluar
Qc = Q1 - Q2
= 82360.75679 - 82101.0566
= 259.700223 kj/jam

Cooling water yang digunakan dengan suhu 30°C, dengan keluaran 45°C

Cp air = 4.1787 kJ/kg.K 0.99873 kkal/kg.K

$$Q = m. Cp. \Delta T$$

$$m = \frac{Q}{Cp.\Delta T}$$

$$= \frac{259.7002225}{0.998733 \ . \ 15}$$

$$= 17.33530733 \text{ kg/jam}$$

Neraca Panas Cooling Conveyor (J-364)		
Komponen	Qin (kkal/jam)	Q Out (kkal/jam)
	27	28
$C_{18}H_{35}NO_{(l)}$	1.864175633	1.864175633
$C_{18}H_{35}NO_{(s)}$	82035.72133	82035.72133
$C_{18}H_{34}O_{2(l)}$	308.1499217	60.58622981
$CO(NH_2)_{2(s)}$	8.9440344	1.689080189
$AlCl_{3(s)}$	3.552886305	0.695575734
$CHCl_{3(l)}$	1.146296508	0.223415528
$H_2O_{(l)}$	1.378143852	0.276758953
Qcw		259.7002225
Total	**82360.75679**	**82360.75679**

APPENDIX C
SPESIFIKASI ALAT

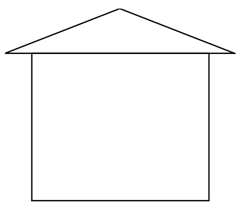
Kapasitas Produksi	=	30000	ton/tahun
Waktu Operasi	=	24	jam/hari
	=	330	hari/tahun
Satuan Massa	=	kg/jam	
Satuan Panas	=	kcal/jam	

Konversi :

1	kg	=	2,2046	lb	1	ft	=	0,3048	m
1	gr/cc	=	62,43	lb/cuft			=	12	in
1	atm	=	14,696	psi	1	lb/cuft	=	16,0185	kg/m^3
1	cuft	=	0,0283	m^3	1	hp	=	550	lb.ft/s
1	cuft/min	=	7,4805	gpm	1	kcal	=	4,184	kj
1	lbf/ft^2	=	0,00694	psi	1	btu	=	1,0551	kj
							=	0,2522	kcal

1. GUDANG UREA (F-110)

Fungsi = Menyimpan urea dari supplier
Type = Bangunan Segi 4
Dasar Pemilihan = Digunakan sebagai tempat penyimpan padatan
Kondisi Operasi = Tekanan = 1 atm
Suhu = 30 °C
Waktu penyimpanan = 7 hari



Perhitungan
Komposisi bahan masuk :

Komponen	Berat (kg/jam)	Fraksi Berat	ρ (gr/ml)
$CO(NH_2)_2$	898,02	0,99	1,32
H_2O	9,07	0,01	1
Total	**907,0893517**	**1,00**	**2,32**

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62{,}43 \text{ lb/cuft}$$

$$= \frac{1}{\left(\frac{0{,}99}{1{,}32} + \frac{0{,}01}{1{,}00} \right)} \times 62{,}43 \text{ lb/cuft}$$

$$= 82{,}1447 \text{ lb/cuft}$$

Rate Massa = 907,0893517 kg/jam
= 1999,7692 lb/jam

$$\text{Rate Volumetrik} = \frac{\text{Rate massa}}{\text{Densitas}}$$

$$= \frac{1999{,}7692 \text{ lb/jam}}{82{,}1447 \text{ lb/cuft}}$$

$$= 24{,}3445 \text{ cuft/jam}$$

Direncanakan untuk 7 hari proses, 1 buah gudang,
sehinga volume bahan adalah

Volume bahan = Rate Volumetrik x Waktu tinggal
= 24,3445 cuft/jam x 24 x 7
= 4089,8691 cuft

Asumsi volume bahan mengisi 80% dari volume gudang (faktor keamanan)

$$\text{Volume gudang} = \frac{\text{Volume bahan}}{80\%}$$

$$= \frac{4089{,}8691}{80\%} \text{ cuft}$$

$$= 5112{,}3364 \text{ cuft}$$

Dimensi gudang penyimpanan

Panjang = 2x

Lebar = x

Tinggi = x

Volume gudang = p x l x t

$5112{,}3364 = 2\ x^3$

$2556{,}1682 = x^3$

$x = 13{,}6730$ ft

Sehingga :

Panjang	=	27,3460	ft	=	8,3350	m
Lebar	=	13,6730	ft	=	4,1675	m
Tinggi	=	13,6730	ft	=	4,1675	m

Luas Alas = p x l
= 27,3460 x 13,6730
= 373,9007 ft^2

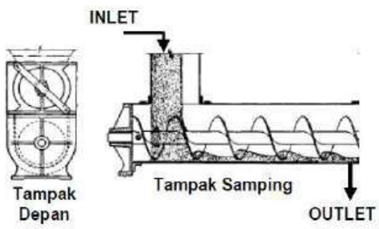
Volume Gudang = p x l x t
= 27,3460 x 13,6730 x 13,6730
= 5112,3364 cuft
= 144,6791 m^3

Spesifikasi :

Fungsi	:	Menampung urea dari supplier
Kapasitas	:	5112,3364 cuft
Type	:	Bangunan Segi 4
Dasar Pemilihan	:	Digunakan untuk menampung padatan
Waktu Penyimpanan	:	7 hari proses
Panjang Gudang	:	27,3460 ft = 8,3350 m
Lebar Gudang	:	13,6730 ft = 4,1675 m
Tinggi Gudang	:	13,6730 ft = 4,1675 m
Jumlah	:	1

2 SCREW CONVEYOR-1 (J-111)

Fungsi = Memindahkan urea dari gudang ke bucket elevator
Type = Plain spouts or chutes
Dasar Pemilihan = Umum digunakan untuk padatan dengan sistem tertutup



Feed masuk screw conveyor

Komponen	Berat (kg/jam)	Fraksi Berat	ρ (gr/ml)
$CO(NH_2)_2$	898,02	0,99	1,32
H_2O	9,070893517	0,01	1
Total	**907,0893517**	**1,00**	**2,32**

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62{,}43 \text{ lb/cuft}$$

$$= \frac{1}{\left(\frac{0{,}99}{1{,}32} + \frac{0{,}01}{1}\right)} \times 62{,}43 \text{ lb/cuft}$$

$$= 82{,}1447 \text{ lb/cuft}$$

Rate Massa = 907,0893517 kg/jam
= 1999,7692 lb/jam

$$\text{Rate Volumetrik} = \frac{\text{Rate massa}}{\text{Densitas}}$$

$$= \frac{1999{,}7692}{82{,}1447}$$

= 24,34 cuft/jam
= 0,4057 cuft/menit
= 3,0351 gpm

$$\text{Power Motor} = \frac{C \times L \times W \times F}{33000}$$

Keterangan : C = Kapasitas (cuft/menit)
L = Panjang (ft)
W = Densitas bahan (lb/cuft)
F = Faktor bahan

Dari **Badger; Hal.627**, didapatkan F = 4

Asumsi Panjang Conveyor L = 30 ft

$$\text{Power Motor} = \frac{0{,}4057 \times 30 \times 82{,}1447 \times 4}{33000}$$

= 0,1212 hP

Untuk power hp<2, maka dikalikan 2 **(Badger :713)**

Power Motor = 0,1212 x 2

= 0,2424 hp

Efisiensi Motor = 80% maka,

$$\text{Power Motor} = \frac{0{,}2424}{80\%}$$

= 0,3030 = 1 hP

Dari **Perry 7ed, Tabel 21-6 hal.21-8**, berdasarkan kapasitas didapatkan :

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 :

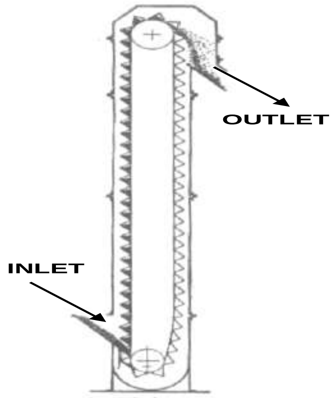
Fungsi	=	Memindahkan bahan dari gudang penyimpanan urea ke bucket elevator
Type	=	Plain spouts or chutes
Dasar pemilihan	=	Umum digunakan untuk padatan dengan sistem tertutup
Kapasitas	=	907,0894 kg/jam
Rate volumetrik	=	3,0351 gpm
Diameter flight	=	9 in
Diameter pipa	=	2 1/2 in
Diameter of shaft	=	2 in
Kecepatan (rpm)	=	40
Elevasi	=	Horizontal
Panjang	=	30 ft
Efisiensi	=	80%
Power	=	1 hP
Jumlah	=	1 buah

3 BUCKET ELEVATOR-1 (J-112)

Fungsi : Memindahakn urea dari srew conveyor ke Hopper

Type : Centrifugal Discharge Bucket Elevator

Dasar Pemilihan : Untuk memindahkan bahan dengan ketinggian tertentu



Rate massa = 907,0893517 kg/jam

= 0,9071 ton/jam

Dari Perry 7ed, Tabel. 21-8, Dipilih *bucket elevator* dengan spesifikasi sebagai berikut:

Kapasitas maksimum = 14 ton/jam

Tinggi *bucket* = 25 ft

Perhitungan *power* :

Power pada *head shaft* = 1 hP

Power tambahan = 0,02 hP/ft

= 0,02 hP/ft x 25 ft

= 0,5 hP

Power total = 1 + 0,5

= 1,5 hP

Efisiensi motor = 80%

Power total $= \dfrac{1,5}{80\%}$

= 1,88 hP ≈ 2 hP

Spesifikasi :

Fungsi = Memindahkan Urea ke Hopper

Type = Centrifugal Discharge Bucket Elevator

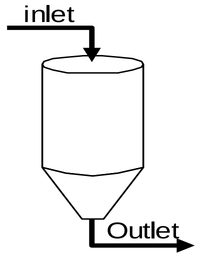
Kapasitas maksimum = 14 ton/jam

Ukuran bucket = 6 in x 4 in x 4 1/4 in

Tinggi bucket	=	25	ft
Bucket spacing	=	12	in
Ukuran *feed* (max)	=	3/4	in
Bucket speed	=	225	ft/mnt
Putaran *head shaft*	=	43	rpm
Lebar *belt*	=	7	in
Power total	=	2	hP
Bahan	=	*Carbon Steel*	
Jumlah	=	1	buah

4 HOPPER-1 (F-113)

Fungsi	:	Menampung sementara urea dari bucket elevator
Type	:	Silinder tegak dengan tutup bawah berbentuk conis
Dasar Pemilihan	:	Umum digunakan unruk menampung padatan



Komponen bahan masuk

Komponen	Berat (kg/jam)	Fraksi Berat	ρ (gr/ml)
$CO(NH_2)_2$	898,02	0,99	1,32
H_2O	9,07	0,01	1
Total	907,09	1,00	2,32

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62,43 \text{ lb/cuft}$$

$$= \frac{1}{\left(\frac{0,99}{1,32} + \frac{0,01}{1} \right)} \times 62,43 \text{ lb/cuft}$$

$$= 82,1447 \text{ lb/cuft}$$

Rate Massa = 907,0893517 kg/jam
= 1999,7692 lb/jam

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

$$= \frac{1999,7692 \text{ lb/jam}}{82,14 \text{ lb/cuft}}$$

$$= 24,3445 \text{ cuft/jam}$$

Direncanakan, waktu tinggal = 1 jam

Volume bahan = Rate volumetrik x waktu tinggal
= 24,3445 x 1
= 24,3445 cuft

Asumsi bahan mengisi 80% volume tangki, maka :

$$\text{Volume tangki} = \frac{\text{Volume bahan}}{80\%} = \frac{24{,}3445}{80\%} = 30{,}4306 \text{ cuft}$$

Menentukan dimensi tangki

Asumsi dimensi ratio H/D = 2 **(Ulrich T.4-27)**

H = 2 D

$$\text{Volume tangki} = \frac{\pi}{4} \times D^2 \times H$$

$$30{,}4306 = 0{,}785 \times D^2 \times 2 D$$

$$30{,}4306 = 1{,}57 \; D^3$$

$$19{,}3825 = D^3$$

D = 2,6862 ft
= 32,2343 in
= 0,8188 m

H = 2 D
= 5,3724 ft
= 64,4686 in
= 1,6375 m

H bahan = 80% H
= 80% x 5,3724
= 4,2979 ft
= 1,3100 m

P operasi = 1 atm
= 14,7 psi

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

P design = 14,7 x 1,1
= 16,17 psi

Menentukan Tebal Minimum Shell

Tebal shell berdasarkan ASME code untuk cylindrical tank :

$$ts_{min} = \frac{P \times ri}{f \; E - 0{,}6 \; P} + C$$

Keterangan :

ts_{min} = tebal shell minimum (in)

P = tekanan tangki (psi)

ri = jari-jari tangki (in; 1/2D) =
C = faktor korosi (in: 1/8D) **(Brownell, pg 254)**
E = faktor pengelasan (double welded; 0,8)
f = allowable stress, bahan konstruksi Carbon Steel SA-283 Grade C
maka, f all = 12650 psi **(Brownell, T.13-1, pg 251)**

Asumsi tebal shell = 3/16 in

$$ts_{min} = \frac{P \times ri}{f\ E - 0{,}6\ P} + C$$

$$3/16 = \frac{16{,}17 \times 16{,}1171}{f \times 0{,}8 - 0{,}6 \times 16{,}17} + 1/8$$

$$1/16 = \frac{260{,}6142}{0{,}8\ f - 9{,}7020}$$

$$0{,}05\ f - 0{,}6064 = 260{,}6142$$

$$0{,}05\ f = 261{,}2206$$

$$f = 5224{,}4118 \text{ psi}$$

f hitung lebih kecil dari f *allowable* , jadi tebal shell 3/16 memenuhi

Menghitung Tutup Bawah Berbentuk Conical

Untuk tebal tutup atas disamakan dengan tebal tutup bawah, karena tutup bawah lebih banyak menerima beban

$$tc = \frac{P \times Di}{2 \cos \alpha\ (f\ E - 0{,}6\ P)} + C$$

Dengan α = 30 °

Asumsi tebal *shell* = 3/16 in

$$tc = \frac{P \times Di}{2 \cos \alpha\ (f\ E - 0{,}6\ P)} + C$$

$$3/16 = \frac{16{,}2 \times 32{,}2343}{2 \cos 30\ (f \times 0{,}8 - 0{,}6 \times 16{,}17)} + 1/8$$

$$1/16 = \frac{521{,}2284299}{1{,}73205\ ((f\ 0{,}8) - (9{,}7020))}$$

$$1/16 = \frac{521{,}2284}{1{,}3856\ f - 16{,}8044}$$

$$0{,}086603\ f - 1{,}0503 = 521{,}2284$$

$$0{,}086603\ f = 520{,}1782$$

$$f = 6006{,}5000 \text{ psi}$$

f hitung lebih kecil dari f *allowable* , jadi tebal shell 3/16 memenuhi

Tinggi Conical

$$h = \frac{tg\ \alpha \times (D - m)}{2}$$ **(Hesse, pers 4-17)**

Dengan : α = sudut conis 30 °
D = diameter tangki (ft)
m = flat sport diameter = 12 in = 1 ft

$$h = \frac{tg\ \alpha \times (D - m)}{2}$$

$$h = \frac{tg\ (30) \times (2{,}6862 - 1)}{2}$$

$$h = \frac{0{,}5774 \times 1{,}6862}{2}$$

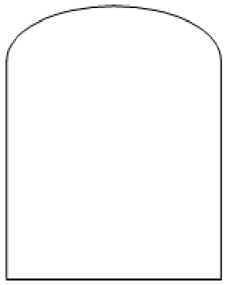
$$h = 0{,}4868 \text{ ft}$$

Spesifikasi :

Fungsi	=	Menampung sementara urea dari *Bucket Elevator*
Type	=	Silinder tegak dengan tutup atas datar dan bawah conical
Dasar pemilihan	=	Umum digunakan untuk menampung padatan
Kapasitas	=	24,3445 ft
Diameter tangki	=	2,6862 ft
Tinggi tangki	=	5,3724 ft
Tebal shell	=	3/16 in
Tebal tutup bawah	=	3/16 in
Tebal tutup atas	=	3/16 in
Tinggi conical	=	0,4868 ft
Cone conical	=	30 °
Jumlah	=	1 buah
Bahan konstruksi	=	Carbon Steel SA-283 Grade C

5 TANGKI ASAM OLEAT (F-120)

Fungsi = Menampung asam oleat dari supplier
Type = Silinder tegak, tutup bawah datar dan tutup atas torispherical
Dasar Pemillihan = Umum digunakan untuk liquid pada tekanan atmosfer
Kondisi Operasi = Tekanan operasi = 1 atm
Suhu operasi = 30 °C
Waktu tinggal = 3 hari



Komponen bahan masuk :

Komponen	Berat (kg/jam)	Fraksi berat	ρ (gr/ml)
$C_{13}H_{34}O_2$	4220,686753	0,99	0,895
H_2O	42,63319953	0,01	1
Total	**4263,319953**	**1**	**1,895**

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62{,}43 \text{ lb/cuft}$$

$$= \frac{1}{\left(\frac{0{,}99}{0{,}895} + \frac{0{,}01}{1}\right)} \times 62{,}43 \text{ lb/cuft}$$

$$= 55{,}9336 \text{ lb/cuft}$$

Rate Massa = 4263,319953 kg/jam
= 9398,9152 lb/jam

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

$$= \frac{9398{,}9152 \text{ lb/jam}}{55{,}93 \text{ lb/cuft}}$$

$$= 168{,}0371 \text{ cuft/jam}$$

Direncanakan penyimpanan untuk 7 hari proses, 1 buah tangki sehingga volume bahan :

Volume bahan = Rate volumetrik x waktu tinggal
= 168,0371 x 24 x 7
= 28230,2284 cuft

Asumsi bahan mengisi 80% volume tangki, maka :

Volume tangki $= \dfrac{\text{Volume bahan}}{80\%}$

$= \dfrac{28230{,}2284}{80\%}$

$=$ 35287,7856 cuft

Menentukan dimensi tangki

Asumsi dimensi ratio H/D = 2 **(Ulrich T.4-27)**

H = 2 D

Volume silinder $= \dfrac{\pi}{4} \times D^2 \times H$

$= 0{,}785 \times D^2 \times 2\ D$

$= 1{,}57\ D^3$

Tutup atas menggunakan torispherical dished, sehingga :

V tutup atas = 0,000049 D^3 (Brownell; pers. 5.11, hal. 88)

jika diambil α = 30 °

Volume tangki = V silinder + V tutup atas

35287,7856 = 1,57 D^3 + 0,000049 D^3

35287,7856 = 1,5700 D^3

D^3 = 22475,5951 H = 2 D

D = 28,2209 ft = 56,44174 ft

= 338,6504 in = 677,300882 in

= 8,6017 m = 17 m

Menentukan tinggi liquid dalam shell

Volume liquid $= \dfrac{\pi}{4} \times D^2 \times H$

28.230,2284 = 0,785 x 796,4175 x H

28.230,2284 = 625,1877 H

H liq = 45,1548 ft

Menentukan Tekanan Design

P operasi = 1 atm = 14,7 psi

P hidrostatis $= \rho \times g/gc \times H_L$

$= 55{,}9336\ \dfrac{\text{lbm}}{\text{cuft}} \times 1\ \dfrac{\text{lbf}}{\text{lbm}} \times 45{,}1548\ \text{ft}$

$= 2525{,}669708\ \dfrac{\text{lbf}}{\text{ft}^2}$

= 17,5394 psi

P design = P operasi + P hidrostatis

= 14,7 + 17,5394

= 32,2394 psi

Untuk faktor keamanan, P design dipilih 10% lebih besar

P design = 1,1 x 32,2394

= 35,4633 psi

Menentukan Ketebalan Dinding Tangki

Tipe material penyusun tangki adalah Stainles Steel. Hal ini disebabkan :

- Mempunyai allowable stress yang besar
- Harga yang relatif lebih murah

Penentuan tebal shell :

$$t_{min} = \frac{P \quad X \quad ri}{f \quad E \ - \ 0{,}6 \quad P} + C$$

Dimana :

t_{min}	= tebal shell minimum	(in)	
P	= tekanan tangki	(psi)	
ri	= jari-jari tangki	(in; 1/2D) =	
C	= faktor korosi	(in: 1/8D)	**(Brownell, pg 254)**
E	= faktor pengelasan	(double welded; 0,8)	
f	= Stress allowable, bahan konstruksi stainless steel tipe AISI-348, maka f all = 34.800 lb/in² **(Perry 7ed; T.28-11)**		

Asumsi tebal shell = 1/4 in

$$t_{min} = \frac{P \quad x \quad ri}{f \quad E \ - \ 0{,}6 \quad P} + C$$

$$1/4 = \frac{35{,}4633103 \quad x \quad 169{,}3252}{f \quad x \quad 0{,}8 \ - \ 0{,}6 \quad x \quad 35{,}46} + 1/8$$

$$1/8 = \frac{6004{,}8328}{0{,}8 \quad f \ - \ 21{,}2780}$$

$0{,}1 \quad f \ - \ 2{,}6597 = 6004{,}8328$

$0{,}10 \quad f = 6007{,}4926$

$f = 60074{,}9258$ psi

f hitung lebih kecil dari f *allowable* , jadi tebal shell 3/16 memenuhi

Menentukan Tebal Tutup Atas dan Bawah

Tutup atas dan bawah dipilih torispherical

OD = ID + 2 ts

= 338,650 + 2 (1/4)

= 339 in

Berdasarkan **Tabel 5.7 Brownell** didapatkan :

ts = 7/8

icr = 13 in

rc = 170 in

$$\frac{icr}{rc} = 7{,}6\%$$

karena icr > 6% rc, maka digunakan persamaan 7.76 dan 7.77

Tebal Standart Toripherical Dished (atas)

$$th = \frac{P \times rc \times W}{2\ f\ E - 0{,}2\ P} + C$$

Dimana:

th = tebal head (in)

W = faktor intensifikasi stress

f = Stress allowable, bahan konstruksi stainless steel tipe AISI-348,
maka f all = 34.800 lb/in² (Perry 7ed; T.28-11)

C = faktor korosi (in) = 1/8 , 10 tahun
(Tabel 6. Timmerhaus, hal.542)

E = faktor pengelasan digunakan double welded E = 0,8
(Tabel 5-7, Brownell, hal.254)

P = tekanan desain

Faktor Intensifikasi stress (W)

$$W = \frac{1}{4} \times \left(3 + \sqrt{\frac{rc}{icr}}\right)$$

$$= \frac{1}{4} \times 3 + \sqrt{\frac{170}{13}}$$

$$= 1{,}6541 \text{ in}$$

Sehingga tebal tutup atas :

Asumsi tebal head = 5/16

$$th = \frac{P \times rc \times W}{2\ f\ E - 0{,}2\ P} + C$$

$$5/16 = \frac{35{,}4633 \times 170 \times 1{,}6541}{2 \times f \times 0{,}8 - 0{,}2 \times 35{,}46331} + 1/8$$

$$0{,}19 = \frac{9971{,}8793}{1{,}6\ f - 7{,}0927}$$

$$0{,}3\ f - 1 = 9971{,}8793$$

$$f = 33244{,}031$$

f hitung lebih kecil dari f *allowable* , jadi tebal tutup atas 5/16 memenuhi

Digunakan tebal head standart = 5/16 in

Tebal botton = tebal head = 5/16 in

untuk th = 5/16 in, maka sf = 1,5 - 3,5

(Tabel 5.6. Brownell, hal.88)

Diambil sf = 2

Menghitung tinggi tutup atas (OA)

BC = rc - icr
= 170 - 13
= 157 in

$AB = \frac{1}{2} Di - icr$

$= \frac{1}{2} \times 338{,}650 - 13$

= 156,325 in

$b = rc - (BC^2 - AB^2)^{0,5}$

$= 170 - (24649 - 24438)^{0,5}$

= 155 in

Jadi, tinggi tutup adalah

OA = b + sf + t
= 155 + 2 + 5/16
= 157,7720 in
= 13,1477 ft

untuk tebal tutup bawah datar karena tutup menumpang diatas semen, maka
tebal tutup = 1/4 in (Brownell & Young; 58)

Spesifikasi :

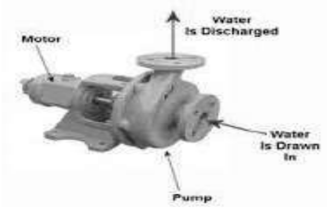
Fungsi	=	Menampung asam oleat dari supplier
Type	=	Tangki berbentuk silinder tegak dengan tutup atas berbentuk Torispherical Head dan tutup bawah plate datar
Volume	=	35287,7856 cuft
Diameter shell	=	28,2209 ft
Tinggi shell	=	56,44174 ft
Tinggi tutup atas	=	13,15 ft
Tebal shell	=	1/4 in
Tebal tutup atas	=	5/16 in
Tebal tutup bawah	=	1/4 in
Bahan konstruksi	=	Stainless Steel AISI-348
Jumlah	=	1 buah

6 POMPA-1 (L-121)

Fungsi : Mengalirkan asam oleat dari tangki penyimpanan ke heater

Type : Centrifugal pump

Dasar Pemilihan : Sesuai dengan viskositas < 10 cP dan bahan liquid



Komponen bahan masuk :

Komponen	Berat (kg/jam	Fraksi berat	ρ (gr/ml)
$C_{18}H_{34}O_2$	4220,68675	0,99	0,895
H_2O	42,6331995	0,01	1
Total	**4263,31995**	**1**	**1,895**

Rate massa = 4263,32 kg/jam

= 9398,915 lb/jam

ρ campuran = 55,93358 lb/cuft

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

$$= \frac{9398{,}915\ \text{lb/jam}}{55{,}93358\ \text{lb/cuft}}$$

= 168,0371 cuft/jam

= 2,800618 cuft/mnt

= 0,046677 cuft/s

= 20,95142 gpm

Asumsi aliran turbulen

Di optimum untuk aliran turbulen, Nre > 2100, digunakan persamaan :

$Di_{opt} = 3{,}9 \times qf^{0,45} \times \rho^{0,13}$ **(Peters, 4 ed, pers.15 : 496)**

Dengan :

Di opt = diameter optimum ; in

qf = fluid flow rate ; cuft/s

ρ = fluid density ; lb/cuft

Di_{opt} = 3,9 x 0,251823 x 1,68732

= 1,657136 in

Dipilih pipa 2 1/2 in, sch 40 **(Mc Cabe, 5ed, App.5)**

OD = 2,9 in

ID = 2,5 in = 0,2058 ft = 0,0627 m

A = 0,3 x π x ID^2
= 0,0332 ft²

$$\text{Kecepatan aliran} = \frac{\text{Rate Volumetrik}}{\text{Area Pipa}}$$

$$= \frac{0{,}04667697 \text{ cuft/s}}{0{,}03323145 \text{ ft}^2}$$

= 1,40460195 ft/s

sg mix = 0,89605

Viskositas Campuran

T = 30 °C = 303,15 K

$$Log_{10}\,\mu = A + \frac{B}{T} + CT + DT^2 \qquad \mu\ Campuran = \sum_{i}^{n} \mu . Xf$$

Data Viskositas Liquid (Yaws, table 22-2)

Komponen	A	B	C	D	μ (cP)
$C_{18}H_{34}O_2$	-6,1303	1689,3	0,008372	-6,45E-06	**1,260185177**
H_2O	-10,2158	1792,5	0,01773	-1,26E-05	**0,551575909**

Komponen	Fraksi berat	μ mix (cP)
$C_{18}H_{34}O_2$	0,99	1,24758332
H_2O	0,01	0,00551576
Total	**1**	**1,25309908**

μ mix = 0,000842 lb/ft.s

$$N_{Re} = \frac{D \times v \times \rho}{\mu}$$

$$= \frac{0{,}2058 \times 1{,}4046 \times 55{,}93358}{0{,}000842083}$$

= 19196,0133 > 2100 (Asumsi turbulen benar)

Dipilih pipa Commercial steel, ε = 0,000046 m
ε/D = 0,000734
f = 0,006 **(Geankoplis,3ed,Fig.2.10-3)**
gc = 32,174 ft.lbm/s² lbf

Digunakan persamaan Bernoulli :

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

Perhitungan friksi berdasarkan **Geankoplis 3ed**, Tabel 2.10-1, hal 93

Sambungan / Fitting	Le/D
Elbow standard 90°	35
Gate valve open	9

Panjang ekuivalen suction, Le

Taksiran panjang pipa lurus = 40 ft

2	Elbow 90°	=	2	x	32	x	0,2058	=	13,168	ft
1	Globe valve	=	1	x	300	x	0,2058	=	61,725	ft
1	Gate valve	=	1	x	7	x	0,2058	=	1,44025	ft

Panjang total pipa (Le) = 116,3333 ft

Friksi yang terjadi :

1 Friksi karena gesekan bahan dalam pipa

$$F_1 = \frac{2f \times v^2 \times L}{gc \times D}$$ **(Peters 4ed, T.1, Hal. 484)**

$$= \frac{2 \times 0{,}006 \times 1{,}972907 \times 116{,}3333}{32{,}174 \times 0{,}2058}$$

$$= 0{,}416051 \text{ ft lbf/lbm}$$

2 Friksi karena kontraksi dari tangki ke pipa

$$F_2 = \frac{K \times v^2}{2 \times \alpha \times gc}$$

$K = 0$ (A tangki >>>A pip **(Peters 4 ed ,hal. 484)**

$\alpha = 1$ (untuk aliran turbulen)

$$F_2 = \frac{0{,}4 \times 1{,}972907}{2 \times 1 \times 32}$$

$$= 0{,}012264 \text{ ft lbf/lbm}$$

3 Friksi karena ekspansi dari pipa ke tangki

$$F_3 = \frac{\Delta v^2}{2 \times \alpha \times gc}$$ ($A1 <<< A2$, maka v_1 dianggap = 0) **(Geankoplis 3ed, Eq.2.10-16, Hal. 93)**

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

$$= \frac{1{,}9729 - 0}{2 \times 1 \times 32}$$

$$= 0{,}03066 \text{ ft lbf/lbm}$$

4 Friksi karena Elbow 90° **(Geankoplis 3ed. 2.10-1 hal 93)**

$$F_4 = K_f \times \frac{v_1^2}{2}$$ **(Geankoplis 3ed, Eq.2.10-16, Hal. 93)**

$$= 1 \times \frac{1{,}9729}{2}$$

$$= 0{,}73984 \text{ ft lbf/lbm}$$

5 Friksi karena Gate Valve

$$F_5 = K_f \times \frac{v_1^2}{2}$$ **(Geankoplis 3ed, Eq.2.10-17, Hal. 93)**

$= 0,2 \times \frac{1,9729}{2}$

$= 0,167697$ ft lbf/lbm

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

$= 0,41605 + 0,0123 + 0 + 0,7398 + 0,1677$

$= 1,3665121$ ft lbf/lbm

$P_1 =$ atm + Ph

$=$ atm + ρ x g/gc x h

$= (15 \times 144) + (55,934 \times 1 \times 12,821)$

$= 2116,8 + 717,13$

$= 2833,9326$ lbf/ft²

$P_2 = 1$ atm

$= 14,7$ lbf/in²

$= 2116,8$ lbf/ft²

$\Delta P = P_2 - P_1$

$= 2116,8 - 2833,9$

$= 717,13257$ lbf/ft²

$\frac{\Delta P}{\rho} = \frac{717,1325666}{55,93358026} = 12,821$ ft lbf/lbm

$\frac{\Delta v^2}{2 \times \alpha \times gc} = \frac{1,9729 - 0}{2 \times 1 \times 32}$

$= 0,0307$ ft lbf/lbm

Asumsi : $Z_1 = 0$ ft

$Z_2 = 12,82115$ ft

$\Delta Z = 12,82115$ ft

g/gc = 1 lbf/lbm

$\Delta Z \frac{g}{gc} = 12,821 \times 1$

$= 12,821$ ft lbf/lbm

Sehingga :

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

$= 12,82115 + 12,821 + 0,0307 + 1,366512$

$= 27,03946$ ft lbf/lbm

$hP = \frac{-Wf \times \text{flowrate (gpm)} \times sg}{3960}$ **(Perry 7ed, pers. 10-51)**

$= \frac{27,039463 \times 20,95142 \times 0,8961}{3960}$

$= 0,128188$ hP

Effisiensi pompa = 52% **(Peters 4 ed ; fig 14-37 ; hal 520)**

$$BhP = \frac{hP}{\eta\ pompa}$$

$$= \frac{0,128188}{0,52}$$

$$= 0,246516\ hP$$

Effisiensi motor = 80% **(Peters 4 ed; fig 14-38 ; hal 521)**

$$Power\ motor = \frac{BhP}{\eta\ motor}$$

$$= \frac{0,246516}{80\%}$$

$$= 0,308145\ hP$$

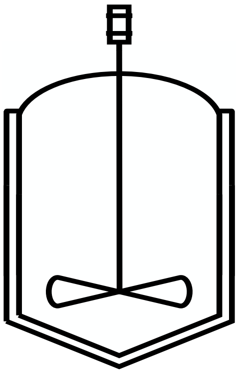
Spesifikasi:

Fungsi	=	Mengalirkan $C_{18}H_{34}O2$ dari tangki penyimpanan ke reaktor
Type	=	Centrifugal pump
Rate volumetrik	=	20,951 gpm
Total Dynamic He	=	27,039 ft lbf/lbm
BhP	=	0,2465 hP
Power Motor	=	0,3081 hP
Effisiensi pompa	=	0,5
Effisiensi motor	=	0,8
Bahan konstruksi	=	Commercial steel
Jumlah	=	1 buah

8. MELTER (M-130)

Fungsi : Tempat meleburkan urea padat menjadi urea cair,

Bentuk : silinder tegak dengan alas dan tutup berbentuk



Massa Masuk

Komponen	Massa (kg/jam)	Fraksi Berat	ρ (gr/ml)
$CO(NH_2)_2$	898,0185	0,9900	1,32
H_2O	9,0709	0,0100	1
Subtotal	907,0894	1,0000	2,32

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62{,}43 \text{ lb/cuft}$$

$$= \frac{1}{\frac{0{,}9900}{1{,}3200} + \frac{0{,}0100}{1}} \times 62{,}43 \text{ lb/cuft}$$

$$= 82{,}1447 \text{ lb/cuft}$$

Rate Massa = 907,089352 kg/jam

= 1999,7692 lb/jam

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

$$= \frac{1999{,}7692 \text{ lb/jam}}{82{,}14 \text{ lb/cuft}}$$

$$= 24{,}3445 \text{ cuft/jam}$$

Asumsi bahan mengisi 80% volume tangki, maka :

$$\text{Volume tangki} = \frac{\text{Volume bahan}}{80\%}$$

$$= \frac{24{,}3445}{80\%}$$

$$= 30{,}4306 \text{ cuft}$$

A Menentukan dimensi tangki

Asumsi dimensi ratio H/D = 2 **(Ulrich T.4-27)**

H = 2 D

$$\text{Volume silinder} = \frac{\pi}{4} \times D^2 \times H$$

$= 0{,}785 \times D^2 \times 2\ D$

$= 1{,}57\ D^3$

Tutup atas dan bawah menggunakan torispherical dished, sehingga :

V tutup atas = 0,000049 D^3 (Brownell; pers. 5.11, hal. 88)

V tutup bawah = 0,000049 D^3

jika diambil α = 30 °

Volume tangki = V silinder + V tutup atas + V tutup bawah

$30{,}4306 = 1{,}57\ D^3 + 0{,}000049\ D^3 + 0{,}000049\ D^3$

$30{,}4306 = 1{,}5701\ D^3$

$D^3 = 19{,}3813$ H = 2 D

D = 2,6861 ft = 5,37227 ft

= 32,2336 in = 64,4672338 in

= 0,8187 m = 1,637467739 m

Menentukan tinggi liquid dalam shell

$$\text{Volume liquid} = \frac{\pi}{4} \times D^2 \times H$$

$24{,}3445 = 0{,}785 \times 7{,}2 \times H$

$24{,}3445 = 5{,}6640\ H$

H liq = 4,2981 ft

Menentukan Tinggi Tuup Bawah (Conical)

$$h = \frac{\text{tg } \alpha \times (D - m)}{2}$$ **(Hesse, pers 4-17)**

Dengan : α = sudut conis = 120 ° 1/2α = 60 °

D = diameter tangki (ft)

m = flat sport diameter = 12 in = 1 ft

$$h = \frac{\text{tg } \alpha \times (D - m)}{2}$$

$$h = \frac{\text{tg } 120 \times (2{,}6861 - 1)}{2}$$

h = 1,4602 ft

= 0,4451 m

Menentukan volume conical

volume conical = $0{,}262 \times H \times (D^2 + D.m + m^2)$

= 0,262 x 1,4602 x 10,901455

= 4,1707 cuft

Menentukan Tekanan Design

P operasi = 1 atm = 14,7 psi

P hidrostatis = ρ x g/gc x H_L

$= 82{,}1447 \dfrac{lbm}{cuft} \times 1 \dfrac{lbf}{lbm} \times 4{,}2981$ ft

$= 353{,}064967 \dfrac{lbf}{ft^2}$

= 2,4518 psi

P design = P operasi + P hidrostatis

= 14,7 + 2,4518

= 17,1518 psi

Untuk faktor keamanan, P design dipilih 10% lebih besar

P design = 1,1 x 17,1518

= 18,867 psi

Menentukan ketebalan dinding Mixer

Penentuan tebal shell :

$$t_{min} = \frac{P \times ri}{f\ E - 0{,}6\ P} + C$$

Dimana :

t_{min} = tebal shell minimum (in)

P = tekanan tangki (psi)

ri = jari-jari tangki (in; 1/2D) =

C = faktor korosi (in: 1/8D) **(Brownell, pg 254)**

E = faktor pengelasan (double welded; 0,8)

f = Stress allowable, bahan konstruksi Carbon steel SA 167 Grade C, maka f all = 18.750 psi **(Brownell, T.13.1 hal.251)**

Asumsi tebal shell = 3/16 in

$$t_{min} = \frac{P \times ri}{f\ E - 0{,}6\ P} + C$$

$$3/16 = \frac{18{,}87 \times 16{,}1168}{f \times 0{,}8 - 0{,}6 \times 18{,}87} + 1/8$$

$$1/16 = \frac{304{,}0762}{0{,}8\ f - 11{,}3202}$$

0,05 f - 0,7075 = 304,0762

0,05 f = 304,7837

f = 6095,6745 psi

f hitung lebih kecil dari f *allowable* , jadi tebal shell 3/16 memenuhi

Menentukan Tebal Tutup Atas

Tutup atas dan bawah dipilih torispherical

OD = ID + 2 ts
= 32,234 + 2 (3/16)
= 33 in

Berdasarkan **Tabel 5.7 Brownell** didapatkan :

ts = 3/16
icr = 2 1/2 in
rc = 40 in

$$\frac{icr}{rc} = 6{,}3\%$$

karena icr > 6% rc, maka digunakan persamaan 7.76 dan 7.77

Tebal Tutup Atas (Torispherical Dished)

$$th = \frac{P \times rc \times W}{2\ f\ E\ -\ 0{,}2\ P} + C$$

Dimana:

th = tebal head (in)
W = faktor intensifikasi stress
f = Stress allowable, bahan konstruksi Carbon steel SA 167 Grade C, maka f all = 18.750 psi **(Brownell, T.13.1 hal.251)**
C = faktor korosi (in) = 1/8 , 10 tahun (Tabel 6. Timmerhaus, hal.542)
E = faktor pengelasan digunakan double welded E = 0,8 (Tabel 5-7, Brownell, hal.254)
P = tekanan desain

Faktor Intensifikasi stress (W)

$$W = \frac{1}{4} \times \left(3 + \sqrt{\frac{rc}{icr}}\right)$$

$$= \frac{1}{4} \times 3 + \sqrt{\frac{72}{4\ 3/8}}$$

= 1,7500 in

Sehingga tebal tutup atas :

Asumsi tebal head = 3/16

$$th = \frac{P \times rc \times W}{2\ f\ E\ -\ 0{,}2\ P} + C$$

$$3/16 = \frac{14{,}7 \times 40 \times 1{,}7500}{2 \times f \times 0{,}8 - 0{,}2 \times 14{,}7} + 1/8$$

$$0{,}06 = \frac{1029{,}0000}{1{,}6\ f - 2{,}9400}$$

0,1 f - 0 = 1029,0000
f = 10291,838

f hitung lebih kecil dari f *allowable* , jadi tebal tutup atas 3/16 memenuhi
Digunakan tebal head standart = 3/16 in
Tebal botton = tebal hea(= 3/16 in
untuk th = 3/16 in, maka sf = 1,5 - 2

(Tabel 5.6. Brownell, hal.88)

Diambil sf = 2

Menghitung tinggi tutup atas (OA)

$$BC = rc - icr$$
$$= 40 - 2{,}5$$
$$= 37{,}5 \text{ in}$$
$$AB = \frac{1}{2} Di - icr$$
$$= \frac{1}{2} \times 32{,}234 - 2{,}5$$
$$= 13{,}6168 \text{ in}$$
$$b = rc - (BC^2 - AB^2)^{0,5}$$
$$= 40 - (1406 - 185{,}4)^{0,5}$$
$$= 5{,}06 \text{ in}$$

Jadi, tinggi tutup adalah

$$OA = b + sf + t$$
$$= 5{,}06 + 2 + 3/16$$
$$= 7{,}2471 \text{ in}$$
$$= 0{,}6039 \text{ ft}$$
$$= 0{,}18408 \text{ m}$$

Tinggi mixer total $= Hs + Hta + Htb$
$= 5{,}3723 + 0{,}6039 + 1{,}4602$
$= 7{,}44$ ft
$= 2{,}2666$ m

Tebal Tutup Bawah (Conical)

Sudut conis = 60 °
e = 0,8

$$th = \frac{P \times Di}{2 \cos \alpha\, (f\,E - 0{,}6\,P)} + C$$

$$3/16 = \frac{18{,}9 \times 32{,}2336}{2 \cos 60 \;(f \times 0{,}8 - 0{,}6 \times 18{,}87)} + 1/8$$

$$1/16 = \frac{608{,}1524255}{1 \;((f \;\; 0{,}8) - (11{,}3202))}$$

$$1/16 = \frac{608{,}1524}{0{,}8000 \; f - 11{,}3202}$$

0,05 f - 0,7075 = 608,1524
0,05 f = 607,4449
f = 12148,8982 psi

f hitung lebih kecil dari f *allowable* , jadi tebal shell 1/4 memenuhi

B. Desain Sistem Pengaduk

Jumlah Baffle = 4

Jumlah Impeller (pengaduk) antara 4 - 16, tetapi umumnya 6 atau 8

Dipilih pengaduk type flat blade turbine dengan jumlah blade 6

Penentuan Dimensi Pengaduk

Tinggi bahan total H_L = 4,2981 ft = 51,577 in

Diameter dalam Dt = 2,6861 ft = 32,2336 in

Ukuran pengaduk diambil dari **MC.cabe ed 7th, hal.247**

$$\frac{Da}{Dt} = \frac{1}{3} \qquad \frac{E}{Dt} = \frac{1}{3} \qquad \frac{W}{Da} = \frac{1}{5}$$

$$\frac{L}{Da} = \frac{1}{4} \qquad \frac{J}{Dt} = \frac{1}{12} \qquad \frac{H}{Dt} = 1$$

Offset 1 $= \frac{1}{2} Da$ Offset 2 $= \frac{1}{6} J$ **(Wallas,hal 288: 1990)**

Keterangan :

Da = Diameter impeller (pengaduk)
Dt = Diameter tangki
L = Panjang blade
W = Lebar blade
E = Jarak impeller (pengaduk) dari dasar tangki
J = Lebar baffle
Offset 1 = Jarak baffle dari dasar tangki
Offset 2 = jarak baffle dari permukaan cairan

Diameter impeller (Da) = 1/3 Dt = 1/3 x 2,6861
= 0,8954 ft

Lebar blade (W) = 1/5 Da = 1/5 x 0,8954
= 0,1791 ft

Panjang blade (L)= 1/4 Da = 1/4 x 0,8954
= 0,2238 ft

Jarak impeller dari dasar (E) = 1/3 Dt = 1/3 x 2,6861
= 0,8954 ft

Lebar baffle (J) = 1/12 Dt = 1/12 x 2,6861
= 0,2238 ft

Tebal pengaduk = 1/10 x 0,2238

= 0,0224 ft

Offset 1 = 1/2 Da = 1/2 x 0,8954

= 0,4477 ft

Offset 2 = 1/6 J = 1/6 x 0,2238

= 0,0373 ft

Panjang baffle = H_L - (Offset 1 + Offset 2)

= 4,2981 - (0,4477 + 0,0373)

= 3,8131 ft

Penentuan Jumlah Pengaduk

$$Sg = \frac{\rho \text{ bahan}}{\rho \text{ reference } (H_2O)}$$

$$Sg = \frac{82{,}1447}{62{,}4}$$

Sg = 1,3164

$$\text{Jumlah Impeller} = \frac{\text{tinggi liquid x sg}}{\text{Diameter tangki}}$$

$$= \frac{4{,}2981 \times 1{,}3164}{2{,}6861}$$

= 2,1064 ≈ 2 buah

Jarak Pengaduk = 1,5 x Da

= 1,5 x 0,8954

= 1,3431 ≈ 3 buah

Penentuan Power Motor

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

$$= \frac{1{,}3164 \times 0{,}00085}{0{,}996}$$

= 0,00112 lb/ft s

V = π x Da x N **(Joshi, hal.389)**

Dimana :

V = Peripheral speed; m/mnt

Untuk pengaduk jenis turbin; V = 200 - 250 m/mnt

Da = Diameter impeller; m = 0,8954 ft = 0,2729 m

N = Putaran pengaduk; rpm

Dipilih putaran pengaduk, N = 250 rpm = 4,17 rps

V = π x Da x N

= 3,14 x 0,2729 x 250

= 214,2354 m/menit **(memenuhi range 200-250 m/menit)**

Bilangan Reynold, Nre :

$$Nre = \frac{\rho \times Da^2 \times N}{\mu}$$

$$Nre = \frac{82,145 \times 0,8017 \times 4,17}{0,001123}$$

$$= 244245,6508 > 2100$$

Untuk NRe > 2100 diperlukan 4 buah baffle sudut 90°

(Perrt 8ed : 18-13)

Power pengaduk :

Untuk NRe > 10.000 perhitungan power menggunakan persamaan berikut

$$P = \frac{Kt}{g} \times \rho \times N^3 \times Da^5$$ **(Ludwig, vol-1, pers 5.5, hal 299)**

Keterangan :

P	= power	; ft.lb/s	
Kt	= faktor mixer (turbin	; 6,3	**(Ludwig, vol-1, T.5-1, hal 301)**
g	= faktor konversi	; 32,2 lbm.ft/lbf/s²	
ρ	= densitas	; lb/cuft	
N	= kec.putaran impelle	; rps	
Da	= diameter impeller	; ft	

$$P = \frac{Kt}{g} \times \rho \times N^3 \times Da^5$$

$$= \frac{6,3}{32,2} \times 82,1447 \times 72,3380 \times 0,5755$$

$$= 669,05742 \text{ lb.ft/s}$$

$$Hp = \frac{P}{550}$$ **(Ludwig, vol-1, Pers.5-6, hal 299)**

$$= \frac{669,05742}{550}$$

$$= 1,2165 \text{ hP}$$

Untuk 2 buah impeller, maka power input = jumlah impeller x hP
= 2 x 1,2165
= 2,43294 hP

Perhitungan losses pengaduk

Gland losses (Kebocoran tenaga akibat poros dan bearing) = 10%

Gland losses 10% = 10% x 2,432936
= 0,2433 hP

Power input dengan gland losses = 2,43294 + 0,2433
= 2,6762 hP

Transmission system losses = 20% (Joshi : 424)
= 20% x 2,6762

= 0,5352 hP

Power input dengan transmission system losses = 2,6762 + 0,5352

= 3,21 hP

Effisiensi motor = 80%

Sehingga power motor = $\dfrac{3,2115}{80\%}$

= 4,014 hP ≈ 1 hP

C. Sistem Pemanas

Perhitungan jaket pemanas

Sebagai media pemanas dengan suhu = 239 °C

Untuk menjaga suhu supaya suhu dalam Melter tetap = 160 °C

Q supply = 227297 kkkal/jam

Suhu bahan masuk	=	30 °C	=	86	°F
Suhu bahan keluar	=	160 °C	=	320	°F
Suhu steam masuk	=	239 °C	=	462,2	°F
Suhu steam keluar	=	239 °C	=	462,2	°F

$\Delta t1$ = 462 °F - 320 °F = 142,2 °F

$\Delta t2$ = 462 °F - 86 °F = 376,2 °F

$$\Delta T_{LMTD} = \frac{\Delta t_2 - \Delta t_1}{2,3 \log \dfrac{\Delta t_2}{\Delta t_1}}$$

$$= \frac{376 - 142}{2,3 \log \dfrac{376}{142}}$$

$$= \frac{234}{0,972}$$

$$= 240,7917 \text{ °F}$$

Temperatur kalorik

$$Tc = \frac{\text{Suhu bahan masuk} + \text{Suhu bahan keluar}}{2}$$

$$= \frac{86 + 320}{2}$$

$$= 203 \text{ °F}$$

$$tc = \frac{\text{Suhu steam masuk} + \text{Suhu steam keluar}}{2}$$

$$= \frac{462,2 + 462}{2}$$

$$= 462,2 \text{ °F}$$

ρ steam = 62,43 lb/cuft

$$\text{Rate Volumetrik} = \frac{\text{Kebutuhan steam}}{\rho \text{ steam}} = \frac{537}{62,43} = 9 \text{ cuft/jam} = 0,0024 \text{ cuft/s}$$

Koefisien Perpindahan Panas bagian luar jaket :

$$hi = 0,36 \; (k/Di) \left[\frac{L^2 \; N \rho}{\mu}\right]^{2/3} \left[\frac{C \mu}{k}\right]^{1/3} \left[\frac{\mu}{\mu_w}\right]^{0,14}$$

Keterangan : **(Kern page.718 eq. 20-1)**

Di = Diameter tangki
L = Da (diameter impeller) = 0,8954 ft
N = Putaran Pengaduk = 250 rpm = 15.000 rph
ρ = Berat jenis larutan = 82,1447 lb/cuft
μ = Viskositas larutan = 0,00112 lb/ft.s
= 4,04443 lb/ft.jam
= 1,67197 cP
C = Kapasitas panas campuran

Komponen	Fraksi (Xf)	Cp (kJ/kg K)
$CO(NH_2)_2$	0,9900	2,5600
H_2O	0,0100	4,1813
Subtotal	1,0000	

1 kJ/kgK = 0,2388459 Btu/lb°F
C = %Cp1 + %Cp2 + %Cp3 +…...+%Cpn
= 0,6153 Btu/lb°F
K = Konduktifitas larutan

$$\text{Kmix} = \frac{0,0677}{sg \; [\; 1 - 0,0003 \; (\Delta T \; LMTD - 32) \;]}$$

$$= \frac{0,0677}{1,3164 \; [\; 1 - 0,0003 \; (240,7917 - 32) \;]}$$

= 0,0548638 Btu/jam.ft.°F

$$\text{Re p} = \left[\frac{L^2 \; N \rho}{\mu}\right]^{2/3}$$

$$= \left(\frac{0,80 \times 15000 \times 250}{0,0011}\right)^{2/3}$$

= 1927494,16

$$\frac{[C\ \mu]}{k}^{1/3} = \left(\frac{0,615 \quad x \quad 0,0011}{0,054863808}\right)^{1/3}$$
$$= 0,2327$$

$$\frac{[\ \mu\ ]}{\mu_w}^{0,14} = \frac{[\ 4,04443\ ]^{0,14}}{1}$$
$$= 1,21607$$

$$hi = 0,36 \quad x \quad \frac{0,05486}{2,6861} \quad x \quad 1.927.494 \quad x \quad 0,2327 \quad x \quad 1,21607$$
$$= 4010,5431 \text{ Btu/jam ft}^2\ ^\circ F$$

Koefisien perpindahan panas bagian dalam jaket
bejana :
Dari Kern tabel 10, dipakai pipa 16 BWG dengan ukuran :
OD = 1,5 in **(Kern, Tabel 10 hal.843)**
ID = 1,37 in
A (flow area) = 1,47 in^2 = 0,000948385 m^2
Surface per lin ft (a) = 0,3925 ft^2

$$v = \frac{W}{\rho \ x \ A} = \frac{537,4772}{\rho \ x \ A}$$
$$= \frac{537,4772}{1000 \text{ kg/m}^3 \quad x \quad 0,000948385 \text{ m}^2}$$
$$= 566,72875 \text{ m/jam}$$
$$= 9,4454792 \text{ m/s}$$
$$= 30,989105 \text{ ft/s}$$

hi = 310 Btu/jam.ft^2.°F **(Kern, Fig.25 hal.835)**

hio
$$= hi \quad x \quad \frac{ID}{OD}$$
$$= 310 \quad x \quad \frac{1,37}{1,5}$$
$$= 283,133 \text{ Btu/jam.ft}^2.^\circ F$$

$$Uc = \frac{hi \ x \ hio}{hi \ + hio}$$
$$= \frac{310 \quad x \quad 283,1}{310 \quad + \quad 283,1}$$
$$= 147,9791$$

Rd = 0,001 **(Kern tabel 12 pg. 845)**

$$\frac{1}{Ud} = \frac{1}{Uc} + Rd$$

$$\frac{1}{Ud} = \frac{1}{147{,}9791} + 0{,}001$$

$$\frac{1}{Ud} = 0{,}0078$$

Ud = 128,904 Btu/jam ft² °F

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

$$= \frac{227297{,}3442}{128{,}904 \times 240{,}7917}$$

$$= 7 \ ft^2$$

Mentukan Tinggi jaket

Tinggi Jaket = Tinggi tangki + Tinggi tutup bawah
= 5,3723 + 1,4602
= 6,8325 ft

Asumsi :

Tebal jaket (tj) = 1/5 in
Tebal air pendingin (s) = 5 in
Effisiensi sambungan las = 0,8
Faktor korosi = 1/8
Bahan konstruksi = Carbon steel SA 167 Grade C
f all = 18750 psi

Do (Shell) = Di + 2 ts
= 32,2336 + 2 (1/5)
= 32,6086 in
= 2,7174 ft

Di (jaket) = Do (Shell) + 2 s
= 32,6086 + 2 (5)
= 42,6086 in
= 3,5507 ft

Do (jaket) = Di (jaket) + 2 tj
= 42,6086 + 2 (1/5)
= 42,9836 in
= 3,5820 ft

Penentuan tebal jaket

P hidrostatis = ρ x g/gc x h liq

$= 62{,}43 \ \frac{lbm}{cuft} \ x \ 1 \ \frac{lbf}{lbm} \ x \ 4{,}2981 \ ft$

$= 268{,}3294 \ \frac{lbf}{ft^2}$

= 1,8634 psi

P jaket = (Pi - Po)jaket

= 18,8670 - 14,7

= 4,1670 psi

P design = P jaket + P hidrostatis

= 4,1670 + 1,8634

= 6,0304 psi

Tebal jaket berdasarkan ASME Code untuk cylindrical tank

$t \ min = \frac{P \ x \ Dij}{2fE - P} + C$

$3/16 = \frac{6{,}0304 \ x \ 42{,}6086}{2 \ x \ f \ x \ 0{,}8 - 6{,}0304} + 1/8$

$1/16 = \frac{256{,}9480}{1{,}6 \ f - 6{,}0304}$

0,1 f - 0,3769 = 256,9480

0,1 f = 257,3249

f = 2573,2486 psi

f all > f design

18750 > 2573,25

Maka, digunakan tj = 3/16 in

Spesifikasi :

Fungsi	=	Tempat meleburkan urea padat menjadi urea cair, untuk keperluan proses
Type	=	Silinder tegal dengan tutup atas torispherical head dan bawah conical dengan dilengkapi pengaduk dan jaket pemanas
Bahan konstruksi	=	
Kapasitas	=	24,3445 cuft
Jumlah	=	1 buah
Dimensi Shell		
Diameter shell	=	2,6861
Tinggi shell	=	5,37227
Tebal shell	=	3/16

Dimensi Tutup

Tebal tutup atas	=	3/16	
Tinggi tutup atas	=	0,6039	
Tebal tutup bawah	=	1/5	
Tinggi tutup bawah	=	1,4602	

Sistem Pengaduk

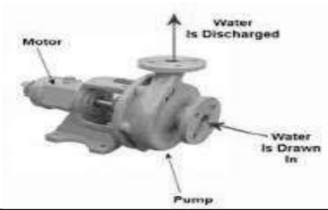
Jenis	=	Tipe flat blade turbin dengan jumlah blade 6 buah	
Jumlah impeller	=	2	
Diameter impeller	=	0,8954	ft
Lebar blade	=	0,1791	ft
Panjang blade	=	0,2238	ft
Jarak impeller	=	0,8954	ft
Lebar baffle	=	0,2238	ft
Putaran	=	250	rpm
Power motor	=	1	hP

Jaket Pendingin

Tinggi jacket	=	6,8325	ft
Tebal jacket	=	1/5	in
Diameter jaket	=	3,5820	ft

9. POMPA-2 (L-131)

Fungsi : Mengalirkan $CO(NH_2)_2$ dari melter ke reaktor
Type : Centrifugal pump
Dasar Pemilihan : Sesuai dengan viskositas < 10 cP dan bahan liquid



Komponen	Massa (kg/jam	Fraksi Berat	ρ (gr/ml)
$CO(NH_2)_2$	898,018458	0,9900	1,32
H_2O	9,07089352	0,0100	1
Subtotal	907,089352	1,0000	2,32

Rate massa = 907,09 kg/jam
= 1999,769 lb/jam
ρ campuran = 82,1447 lb/cuft

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

$$= \frac{1999{,}769 \text{ lb/jam}}{82{,}1447 \text{ lb/cuft}}$$

= 24,3445 cuft/jam
= 0,4057 cuft/mnt
= 0,0068 cuft/s
= 3,0353 gpm

Asumsi aliran turbulen

Di optimum untuk aliran turbulen, Nre > 2100, digunakan persamaan :

$Di_{opt} = 3{,}9 \times qf^{0,45} \times \rho^{0,13}$ **(Peters, 4 ed, pers.15 : 496)**

Dengan :

Di opt = diameter optimum ; in
qf = fluid flow rate ; cuft/s
ρ = fluid density ; lb/cuft

$Di_{opt} = 3{,}9 \times 0{,}1056 \times 1{,}7738$
$= 0{,}7303$ in

Dipilih pipa 1 1/4 in, sch 40 **(Mc Cabe, 5ed, App.5)**

OD = 1,7 in

ID = 1,4 in = 0,1150 ft = 0,0351 m

A = 1/4 x π x ID^2

= 0,0104 ft²

Kecepatan aliran = $\frac{\text{Rate Volumetrik}}{\text{Area Pipa}}$

= $\frac{0,0068 \text{ cuft/s}}{0,01038163 \text{ ft}^2}$

= 0,6514 ft/s

sg bahan = 1,3168

Viskositas Campuran

T = 160 °C = 433,15 K

$$Log_{10}\,\mu = A + \frac{B}{T} + CT + DT^2 \qquad \mu\ Campuran = \sum_{i}^{n} \mu . Xf$$

Data Viskositas Liquid (Yaws, table 22-2)

Komponen	A	B	C	D	μ (cP)
CO(NH2)2	-6,1303	1689,3	0,008372	-6,45E-06	**1,553816478**
H2O	-10,2158	1792,5	0,01773	-1,26E-05	**0,17077495**

Komponen	Fraksi berat	μ mix (cP)
C18H34O2	0,9900	1,53827831
H2O	0,0100	0,00170775
Total	**1**	**1,53998606**

μ mix = 0,001035 lb/ft.s

N_{Re} = $\frac{D \times v \times \rho}{\mu}$

= $\frac{0,1150 \times 0,6514 \times 82,1447}{0,0010}$

= 5946 > 2100 (Asumsi turbulen benar)

Dipilih pipa Commercial steel, = 0,000046 m

ε/D = 0,001312

f = 0 **(Geankoplis,3ed,Fig.2.10-3)**

gc = 32,174 ft.lbm/s² lbf

Digunakan persamaan Bernoulli :

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

Perhitungan friksi berdasarkan **Geankoplis 3ed**, Tabel 2.10-1, hal 93

Sambungan / Fitting	Le/D
Elbow standard 90°	35
Gate valve open	9

Panjang ekuivalen suction, Le

Taksiran panjang pipa lurus = 40 ft

2 Elbow 90°	=	3 x	32	x	0,1150	=	11,0400	ft
1 Globe valve	=	1 x	300	x	0,1150	=	34,5	ft
1 Gate valve	=	1 x	7	x	0,1150	=	0,8050	ft

Panjang total pipa (Le) = 86,3450 ft

Friksi yang terjadi :

1 Friksi karena gesekan bahan dalam pipa

$$F_1 = \frac{2f \times v^2 \times L}{gc \times D}$$ **(Peters 4ed, T.1, Hal. 484)**

$$= \frac{2 \times 0,008 \times 0,4243 \times 86,3450}{32,174 \times 0,1150}$$

$$= 0,1584 \text{ ft lbf/lbm}$$

2 Friksi karena kontraksi dari tangki ke pipa

$$F_2 = \frac{K \times v^2}{2 \times \alpha \times gc}$$

K = 0 (A tangki >>>A pip **(Peters 4 ed ,hal. 484)**

α = 1 (untuk aliran turbulen)

$$F_2 = \frac{0,4 \times 0,4243}{2 \times 1 \times 32}$$

$$= 0,00264 \text{ ft lbf/lbm}$$

3 Friksi karena ekspansi dari pipa ke tangki

$$F_3 = \frac{\Delta v^2}{2 \times \alpha \times gc}$$ (A1 <<< A2, maka v_1 dianggap = 0) **(Peters 4ed, T.1, Hal. 484)**

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

$$= \frac{0,4243 - 0}{2 \times 1 \times 32}$$

$$= 0,0066 \text{ ft lbf/lbm}$$

4 Friksi karena Elbow 90° **(Geankoplis 3ed. 2.10-1 hal 93)**

$$F_4 = K_f \times \frac{v_1^2}{2}$$

$$= 3 \times 0,8 \times \frac{0,4243}{2}$$

$$= 0,4773 \text{ ft lbf/lbm}$$

5 Friksi karena Gate Valve

$$F_5 = K_f \times \frac{v_1^2}{2}$$ **(Geankoplis 3ed, Eq.2.10-17, Hal. 93)**

$$= 0,2 \times \frac{0,4243}{2}$$

$$= 0,0361 \text{ ft lbf/lbm}$$

$\Sigma F = F_1 + F_2 + F_3 + F_4 + F_5$
$= 0{,}1584 + 0{,}0026 + 0{,}01 + 0{,}4773 + 0{,}0361$
$= 0{,}6810$ ft lbf/lbm

$P_1 = 1 \text{ atm} + Ph$
$= 1 \text{ atm} + \rho \ x \ g/gc \ x \ h$
$= (15 \ x \ 144) + (82{,}145 \ x \ 1 \ x \ 5{,}1288)$
$= 2116{,}8 + 421{,}3$
$= 2.538{,}102$ lbf/ft²
$P_2 = 1$ atm
$= 14{,}7$ lbf/in²
$= 2116{,}8$ lbf/ft²
$\Delta P = P_2 - P_1$
$= 2116{,}8 - 2538{,}1$
$= 421{,}3021$ lbf/ft²
$\frac{\Delta P}{\rho} = \frac{421{,}3021}{82{,}1447} = 5{,}1288$ ft lbf/lbm

$\frac{\Delta v^2}{2 \ x \ \alpha \ x \ gc} = \frac{0{,}4243}{2 \ x \ 1 \ x \ 32}$
$= 0{,}0066$ ft lbf/lbm

Asumsi : $Z_1 = 0{,}0000$ ft
$Z_2 = 5{,}1288$ ft
$\Delta Z = 5{,}1288$ ft

$g/gc = 1$ lbf/lbm
$\Delta Z \frac{g}{gc} = 5{,}1288 \ x \ 1$
$= 5{,}1288$ ft lbf/lbm
Sehingga :
$-Wf = \frac{\Delta P}{\rho} + \frac{\Delta Z \ g}{gc} + \frac{\Delta v^2}{2 \ x \ gc \ x \ \alpha} + \Sigma F$
$= 5{,}1288 + 5{,}1288 + 0{,}0066 + 0{,}6810$
$= 10{,}9452$ ft lbf/lbm
$hP = \frac{-Wf \ x \ \text{flowrate (gpm)} \ x \ sg}{3960}$
$= \frac{10{,}9452 \ x \ 3{,}0353 \ x \ 1{,}3168}{3960}$
$= 0{,}0110$ hP

Effisiensi pompa = 52% (Peters 4 ed ; fig 14-37 ; hal 520)

$$BhP = \frac{hP}{\eta \text{ pompa}}$$

$$= \frac{0,0110}{52\%}$$

$$= 0,0212 \text{ hP}$$

Effisiensi motor = 80% (Peters 4 ed; fig 14-38 ; hal 521)

$$\text{Power motor} = \frac{BhP}{\eta \text{ motor}}$$

$$= \frac{0,0212}{80\%}$$

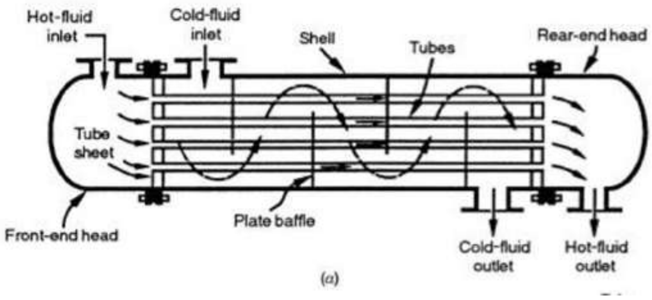
$$= 0,0266 \text{ hP}$$

Spesifikasi:

Fungsi	=	Mengalirkan $CO(NH_2)_2$ dari melter ke reaktor
Type	=	Centrifugal pump
Rate volumetrik	=	3,0353 gpm
Total Dynamic Head	=	10,945 ft lbf/lbm
BhP	=	0,021 hP
Power Motor	=	0,027 hP
Effisiensi pompa	=	52%
Effisiensi motor	=	80%
Bahan konstruksi	=	Commercial steel
Jumlah	=	1 buah

7. HEATER-1 (E-122)

Fungsi	:	Memanaskan asam oleat sebelum masuk reaktor
Type	:	
Kondisi operasi	:	Tekanan = 1 atm
		Suhu = 160 °C



1. Neraca Panas :

Dari neraca massa dan neraca panas diperoleh:

Berat bahan	=	4220,68675	kg/jam
	=	9304,92602	lb/jam
Panas yang dibutuhkan, Q	=	360299,153	kkal/jam
	=	1428826,4	Btu/jam
Steam yang digunakan, W_{steam}	=	851,979008	kg/jam
	=	1878,27292	lb/jam
W_{fluida} dingin	=	671,00	kg/jam
	=	1479,2866	lb/jam

2. Penentuan ΔT_{LMTD}

Hot fluid (°F)		Cold fluid (°F)	Δt
462,2	Higher temp	320	142
462,2	Lower temp	86	376

$$\Delta T_{LMTD} = \frac{\Delta t_2 - \Delta t_1}{2{,}3 \log \frac{\Delta t_2}{\Delta t_1}}$$ **(Kern; Pers. 5.14)**

$$= \frac{142 - 376}{2{,}3 \log \frac{142}{376}}$$

$$= \frac{-234}{-0{,}972}$$

$$= 240{,}792 \text{ °F}$$

$$R = \frac{T1 - T2}{t2 - t1} = \frac{462 - 462}{320 - 86} = 0$$

$$S = \frac{t2 - t1}{T1 - t1} = \frac{248 - 86}{298,4 - 86} = 0,7627$$

F_T = 0,980 **(Kern; Fig. 18)**

Δt = LMTD x F_T (Untuk 1 dan 2 shell and tube)
= 240,792 x 0,980
= 235,976 °F

3. Tc dan tc dipakai temperatur rata-rata

Tc = Tav steam

$$Tc = \frac{T_1 + T_2}{2} = \frac{462,2 + 462,2}{2} = 462,2 \text{ °F}$$

tc = tcav bahan

$$tc = \frac{t_1 + t_2}{2} = \frac{86 + 320}{2} = 203 \text{ °F}$$

(μ = 0,014) steam **(Kern; Fig. 15)**
(μ = 0,025) udara

Dipilih tipe : 1 - 2 Heat Exchanger
Digunakan shell and tube dengan ukuran :
OD, BWG = 3/4 in 16 BWG
Pitch = 1 in Square Pitch
Panjang Tube, L = 12 ft

Berdasarkan Kern: T.10, hal.843

ID = 0,62 in
a't = 0,302 in^2
a" = 0,1623 ft^2/ft panjang
Hot fluid : Steam
Cold fluid : Udara kering

Nilai U_D range = 5-50 Btu/jam.ft^2°F (Cold fluid = Light organics)

Dipilih U_D = 5 Btu/jam.ft^2°F

$$A = \frac{Q}{\Delta T_{LMTD} \times U_D} = \frac{1428826,401}{235,976 \times 5} = 1210,99349 \text{ ft}^2$$

$$\text{Jumlah Tube (Nt)} = \frac{A}{L \times a''} = \frac{1.211 \text{ ft}^2}{12 \times 0,1623 \text{ ft}} = 621,7876 \text{ buah}$$

Asumsi 2 tube passes, dari Kern; tabel 9 diperoleh
Digunakan Nt =
ID Shell = 35 in
Phases = 2
Koreksi U_D :

A = Nt x L x a"
= 622 x 12 x 0,1623
= 1210,9935 ft²

$UD = \dfrac{Q}{A \times \Delta t}$

$= \dfrac{1.428.826}{1210,993 \times 235,976}$

= 5 Btu/j ft²°F

Fluida panas (Tube side)	Fluida dingin (shell side)
4) a't = 0,302 in²	4') B = $\dfrac{ID}{5} = \dfrac{35}{5}$ = 7 in
at = $\dfrac{Nt \times a't}{144 \quad n}$	as = ID x C'B / 144 P_T
= $\dfrac{621,8 \times 0,302}{144 \times 2}$	= $\dfrac{35 \times 0,25 \times 7}{144 \times 2}$
= 0,6520 ft²	= 0,2127 ft²
5) Gt = $\dfrac{W}{at}$	5') Gs = $\dfrac{W}{as}$
= $\dfrac{1878,272922}{0,6520}$	= $\dfrac{1.479}{0,2127}$
= 2880,727642 lb/jam.ft²	= 6.956 lb/jam.ft²
6) Pada Tc = 462,2 °F	6') Pada tc = 203 °F
μ = 0,014 x 2,42	μ = 0,025 x 2,42
= 0,0339 lb/ft.jam	= 0,0605 lb/ft.jam
D = 0,62 in	untuk 3/4 in OD, 1-in square pitch **(Kern, Fig.28)**
= 0,0517 ft	De = 0,95 in
Re.t = $\dfrac{DGt}{\mu}$	= 0,0792 ft
= $\dfrac{0,05167 \times 2880,727642}{0,0339}$	Re.s = $\dfrac{De \times Gs}{\mu}$
= 4.393,081	= $\dfrac{0,0792 \times 6.956}{0,0605}$
	= 9.101,7668
	7') Dari fig. 24 didapat
	jH = 500
	8') tc = 203 °F

	k = 0,0156 Btu/(hr)(ft^2)(^oF/ft) (Tabel 5)
	$= (c \times \mu/k)^{1/3}$
	$= \left(\dfrac{1 \times 0{,}0605}{0{,}0156} \right)^{(1/3)}$
	= 1,5445
	μw = 1 (standart)
	$\varphi s = (\mu/\mu w)^{0,14}$
	= 0,6752
9) Hio untuk kondensasi steam	9') ho = $J_H \times (k/De) \times (c \times \mu / k)^{1/3} \times \varphi s$
Hio = 1500 Btu/j ft² °F (Kern;168)	= 102,7502 Btu/j ft² °F

10) Clean overall coefficient (Uc)

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

$$= \frac{1500 \times 102{,}7502}{1500 + 102{,}7502}$$

= 96,163 Btu/j ft² °F

11) Design overall coefficient (Ud)

Ud = Q / (A x Δt LMTD)

$$= \frac{1.428.826}{1210{,}99349 \times 240{,}792}$$

= 5 Btu/j ft² °F

12)

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

$$= \frac{96{,}163 - 5}{96{,}163 \times 5}$$

= 0,1937 j ft^2 F/BTU

Rd perhitungan > Rd data (Kern ; T 12)

0,1937 > 0,002

maka dari segi faktor kekotoran memenuhi syarat

Pressure drop

Steam (Tube side)	Air (Shell side)
1) Re.t = 4393,081311	1') Re.s = 9.102
f = 0,00035	f = 0,0013
(Kern, Fig.26)	(Kern, Fig.29)
v = 6,466	s = 1,0800
Interpolasi	2') N+1 = 12 L / B
(Kern, Tabel.7)	= 20,5714
s = 0,0025	Ds = 35 / 12

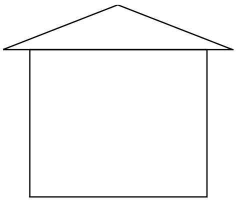
	= 2,9167 ft
2) $\Delta Pt = \dfrac{f.Gt^2.L.n}{5{,}22 \times 10^{10}.Ds.\phi t}$	3') $\Delta Ps = \dfrac{f.Gs^2.Ds.(N+1)}{5{,}22 \times 10^{10}.De.s.\phi t}$
= 0,000669628 psi	= 0,00125225 psi

Spesifikasi :

Fungsi	=	Memanaskan udara menuju rotary dryer
Type	=	Shell and tube, 1-2 exchanger (Fixed tube)
Shell side		
ID	=	35 in
B	=	7 in
n	=	2 Passes
Tube side		
Nt	=	622 buah
L	=	12 ft
OD	=	3/4 in
BWG	=	16 BWG
n	=	1
Pitch	=	Square pitch 1"
Heat exch, area A	=	1210,9935 ft²
Jumlah heat exchanger	=	1
Bahan konstruksi	=	Carbon Steel

10. GUDANG ALUMINIUM KLORIDA (F-140)

Fungsi = Menyimpan aluminium klorida dari supplier
Type = Bangunan Segi 4
Dasar Pemilihan = Digunakan sebagai tempat penyimpan padatan
Kondisi Operasi = Tekanan = 1 atm
Suhu = 30 °C
Waktu penyimpanan = 7 hari



Perhitungan
Komposisi bahan masuk :

Komponen	Berat (kg/jam)	Fraksi Berat	ρ (gr/ml)
$AlCl_3$	42,2069	1,00	2,48
Total	42,2069	1,00	

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62{,}43 \text{ lb/cuft}$$

$$= \frac{1}{\left(\frac{1{,}00}{2{,}48}\right)} \times 62{,}43 \text{ lb/cuft}$$

$$= 154{,}8264 \text{ lb/cuft}$$

Rate Massa = 42,20686753 kg/jam
= 93,0493 lb/jam

$$\text{Rate Volumetrik} = \frac{\text{Rate massa}}{\text{Densitas}}$$

$$= \frac{93{,}0493 \text{ lb/jam}}{154{,}8264 \text{ lb/cuft}}$$

$$= 0{,}6010 \text{ cuft/jam}$$

Direncanakan untuk 30 hari proses, 1 buah gudang,
sehinga volume bahan adalah

Volume bahan = Rate Volumetrik x Waktu tinggal
= 0,6010 cuft/jam x 24 x 30
= 432,7135 cuft

Asumsi volume bahan mengisi 80% dari volume gudang (faktor keamanan)

$$\text{Volume gudang} = \frac{\text{Volume bahan}}{80\%}$$

$$= \frac{432{,}7135}{80\%} \text{ cuft}$$

$$= 540{,}8918 \text{ cuft}$$

Dimensi gudang penyimpanan

Panjang = 2x

Lebar = x

Tinggi = x

Volume gudang = p x l x t

540,8918 = 2 x^3

270,4459 = x^3

x = 6,4669 ft

Sehingga :

Panjang	=	12,9337	ft	=	3,9422	m
Lebar	=	6,4669	ft	=	1,9711	m
Tinggi	=	6,4669	ft	=	1,9711	m

Luas Alas = p x l

= 12,9337 x 6,4669

= 83,6406 ft^2

Volume Gudang = p x l x t

= 12,9337 x 6,4669 x 6,4669

= 540,8918 cuft

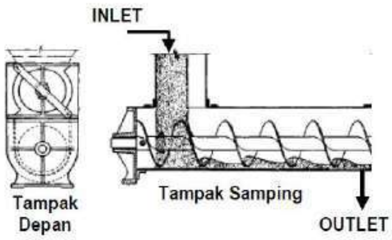
= 15,3072 m^3

Spesifikasi :

Fungsi	=	Menampung aluminium klorida dari supplier
Kapasitas	=	540,8918 cuft
Type	=	Bangunan Segi 4
Dasar Pemilihan	=	Digunakan untuk menampung padatan
Waktu Penyimpanan	=	30 hari proses
Panjang Gudang	=	12,9337 ft = 3,9422 m
Lebar Gudang	=	6,4669 ft = 1,9711 m
Tinggi Gudang	=	6,4669 ft = 1,9711 m
Jumlah	=	1 buah

11. SCREW CONVEYOR-2 (J-141)

Fungsi = Memindahkan $AlCl_3$ dari gudang ke bucket elevator
Type = Plain spouts or chutes
Dasar Pemilihan = Umum digunakan untuk padatan dengan sistem tertutup



Feed masuk screw conveyor

Komponen	Berat (kg/jam)	Fraksi Berat	ρ (gr/ml)
$AlCl_3$	42,2069	1,00	2,48
Total	42,2069	1,00	

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62{,}43 \text{ lb/cuft}$$

$$= \frac{1}{\left(\frac{1{,}00}{2{,}48}\right)} \times 62{,}43 \text{ lb/cuft}$$

$$= 154{,}8264 \text{ lb/cuft}$$

Rate Massa = 42,20686753 kg/jam
= 93,0493 lb/jam

$$\text{Rate Volumetrik} = \frac{\text{Rate massa}}{\text{Densitas}}$$

$$= \frac{93{,}0493}{154{,}8264}$$

= 0,60 cuft/jam
= 0,0100 cuft/menit
= 0,0749 gpm

$$\text{Power Motor} = \frac{C \times L \times W \times F}{33000}$$

Keterangan : C = Kapasitas (cuft/menit)
L = Panjang (ft)

W = Densitas bahan (lb/cuft)
F = Faktor bahan
Dari **Badger; Hal.627**, didapatkan F = 4

Asumsi Panjang Conveyor L = 30 ft

$$\text{Power Motor} = \frac{0{,}0100 \times 30 \times 154{,}8264 \times 4}{33000}$$

= 0,0056 hP

Untuk power hp<2, maka dikalikan 2 **(Badger :713)**

Power Motor = 0,0056 x 2
= 0,0113 hp

Efisiensi Motor = 80% maka,

$$\text{Power Motor} = \frac{0{,}0113}{80\%}$$

= 0,0141 = 1 hP

Dari **Perry 7ed, Tabel 21-6 hal.21-8**, berdasarkan kapasitas didapatkan :

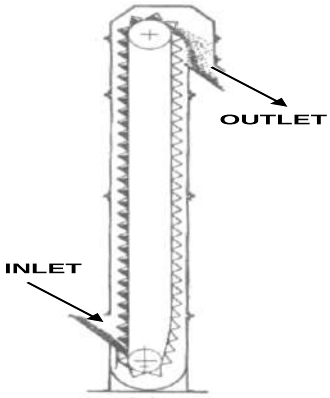
Kapasitas maksimum	=	5	ton/jam
Diameter flight	=	9	in
Diameter pipa	=	2 1/2	in
Diameter of shaft	=	2	in
Hanger center	=	10	ft
Diameter feed section	=	6	in
Kecepatan screw conveyor	=	40	rpm

Spesifikasi :

Fungsi	=	Memindahkan bahan dari gudang penyimpanan $AlCl_3$ ke bucket elevator
Type	=	Plain spouts or chutes
Dasar pemilihan	=	Umum digunakan untuk padatan dengan sistem tertutup
Kapasitas	=	42,20687 kg/jam
Rate volumetrik	=	0,0749 gpm
Diameter flight	=	9 in
Diameter pipa	=	2 1/2 in
Diameter of shaft	=	2 in
Kecepatan (rpm)	=	40
Elevasi	=	Horizontal
Panjang	=	30 ft
Efisiensi	=	80%
Power	=	1 hP
Jumlah	=	1 buah

12. BUCKET ELEVATOR-2 (J-142)

Fungsi	:	Memindahakn aluminium klorida dari Srew Conveyor ke hopper
Type	:	Centrifugal Discharge Bucket Elevator
Dasar Pemilihan	:	Untuk memindahkan bahan dengan ketinggian tertentu



Rate massa = 42,20686753 kg/jam
= 0,0422 ton/jam

Dari Perry 7ed, Tabel. 21-8, Dipilih *bucket elevator* dengan spesifikasi sebagai berikut:

Kapasitas maksimum = 14 ton/jam
Tinggi *bucket* = 25 ft

Perhitungan *power* :

Power pada *head shaft* = 1 hP
Power tambahan = 0,02 hP/ft
= 0,02 hP/ft x 25 ft
= 0,5 hP
Power total = 1 + 0,5
= 1,5 hP
Efisiensi motor = 80%

Power total $= \dfrac{1{,}5}{80\%}$
= 1,88 hP ≈ 2 hP

Spesifikasi :

Fungsi	=	Memindahkan aluminium klorida ke hopper
Type	=	Centrifugal Discharge Bucket Elevator
Kapasitas maksimum	=	14 ton/jam
Ukuran bucket	=	6 in x 4 in x 4 1/4 in
Tinggi bucket	=	25 ft

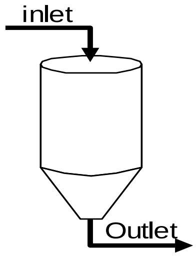
Bucket spacing	=	12 in
Ukuran *feed* (max)	=	3/4 in
Bucket speed	=	225 ft/mnt
Putaran *head shaft*	=	43 rpm
Lebar *belt*	=	7 in
Power total	=	2 hP
Bahan	=	*Carbon Steel*
Jumlah	=	1 buah

13. HOPPER-2 ((F-143)

Fungsi : Menampung sementara aluminium klorida dari bucke elevator

Type : Silinder tegak dengan tutup bawah berbentuk conis

Dasar Pemilihan : Umum digunakan unruk menampung padatan



Komponen bahan masuk

Komponen	Berat (kg/jam)	Fraksi Berat	ρ (gr/ml)
$AlCl_3$	42,2069	1,00	2,48
Total	42,2069	1,00	2,48

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62{,}43 \text{ lb/cuft}$$

$$= \frac{1}{\left(\frac{1{,}00}{2{,}48}\right)} \times 62{,}43 \text{ lb/cuft}$$

$$= 154{,}8264 \text{ lb/cuft}$$

Rate Massa = 42,20686753 kg/jam

= 93,0493 lb/jam

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

$$= \frac{93{,}0493 \text{ lb/jam}}{154{,}83 \text{ lb/cuft}}$$

= 0,6010 cuft/jam

Direncanakan, waktu tinggal = 1 jam

Volume bahan = Rate volumetrik x waktu tinggal

= 0,6010 x 1

= 0,6010 cuft

Asumsi bahan mengisi 80% volume tangki, maka :

$$\text{Volume tangki} = \frac{\text{Volume bahan}}{80\%}$$

$$= \frac{0{,}6010}{80\%}$$

= 0,7512 cuft

Menentukan dimensi tangki

Asumsi dimensi ratio H/D = 2 **(Ulrich T.4-27)**

H = 2 D

$$\text{Volume tangki} = \frac{\pi}{4} \times D^2 \times H$$

$0{,}7512 = 0{,}785 \times D^2 \times 2\ D$

$0{,}7512 = 1{,}57\ D^3$

$0{,}4785 = D^3$

D = 0,7822 ft
= 9,3859 in
= 0,2384 m

H = 2 D
= 1,5643 ft
= 18,7717 in
= 0,4768 m

H bahan = 80% H
= 80% x 1,5643
= 1,2514 ft
= 0,3814 m

P operasi = 1 atm
= 14,7 psi

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

P design = 14,7 x 1,1
= 16,17 psi

Menentukan Tebal Minimum Shell

Tebal shell berdasarkan ASME code untuk cylindrical tank :

$$ts_{min} = \frac{P \times ri}{f\ E - 0{,}6\ P} + C$$

Keterangan :

ts_{min} = tebal shell minimum (in)
P = tekanan tangki (psi)
ri = jari-jari tangki (in; 1/2D) =
C = faktor korosi (in: 1/8D) **(Brownell, pg 254)**
E = faktor pengelasan (double welded; 0,8)
f = allowable stress, bahan konstruksi Carbon Steel SA-283 Grade C
maka, f all = 12650 psi **(Brownell, T.13-1, pg 251)**

Asumsi tebal shell = 3/16 in

$$ts_{min} = \frac{P \times ri}{f\ E - 0{,}6\ P} + C$$

$$3/16 = \frac{16{,}17 \times 4{,}6929}{f \times 0{,}8 - 0{,}6 \times 16{,}17} + 1/8$$

$$1/16 = \frac{75{,}8847}{0{,}8\ f - 9{,}7020}$$

$$0{,}05\ f - 0{,}6064 = 75{,}8847$$

$$0{,}05\ f = 76{,}4910$$

$$f = 1529{,}8208 \text{ psi}$$

f hitung lebih kecil dari f *allowable* , jadi tebal shell 3/16 memenuhi

Menghitung Tutup Bawah Berbentuk Conical

Untuk tebal tutup atas disamakan dengan tebal tutup bawah, karena tutup bawah lebih banyak menerima beban

$$tc = \frac{P \times Di}{2 \cos \alpha\ (f\ E - 0{,}6\ P)} + C$$

Dengan α = 30 °

Asumsi tebal *shell* = 3/16 in

$$tc = \frac{P \times Di}{2 \cos \alpha\ (f\ E - 0{,}6\ P)} + C$$

$$3/16 = \frac{16{,}2 \times 9{,}3859}{2 \cos 30\ (f \times 0{,}8 - 0{,}6 \times 16{,}17)} + 1/8$$

$$1/16 = \frac{151{,}7693319}{1{,}73205\ ((f\ 0{,}8) - (9{,}7020))}$$

$$1/16 = \frac{151{,}7693}{1{,}3856\ f - 16{,}8044}$$

$$0{,}086603\ f - 1{,}0503 = 151{,}7693$$

$$0{,}086603\ f = 150{,}7191$$

$$f = 1740{,}3538 \text{ psi}$$

f hitung lebih kecil dari f *allowable* , jadi tebal shell 3/16 memenuhi

Tinggi Conical

$$h = \frac{tg\ \alpha \times (D - m)}{2}$$ **(Hesse, pers 4-17)**

Dengan : α = sudut conis 30 °
D = diameter tangki (ft)
m = flat sport diameter = 6 in = 1 ft

$$h = \frac{tg\ \alpha \times (D - m)}{2}$$

$$h = \frac{tg\ (\ 30\ )\ \ x\ \ (\ 0{,}7822\ -\ 1\ )}{2}$$

$$h = \frac{0{,}5774\ \ x\ \ 0{,}2822}{2}$$

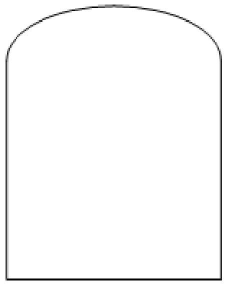
$$h = 0{,}0815 \text{ ft}$$

Spesifikasi :

Fungsi	=	Menampung sementara aluminium klorida dari Bucket Elevator
Type	=	Silinder tegak dengan tutup atas datar dan bawah conical
Dasar pemilihan	=	Umum digunakan untuk menampung padatan
Kapasitas	=	0,6010 ft
Diameter tangki	=	0,7822 ft
Tinggi tangki	=	1,5643 ft
Tebal shell	=	3/16 in
Tebal tutup bawah	=	3/16 in
Tebal tutup atas	=	3/16 in
Tinggi conical	=	0,0815 ft
Cone conical	=	30 °
Jumlah	=	1 buah
Bahan konstruksi	=	Carbon Steel SA-283 Grade C

14. TANGKI KLOROFORM (F-150)

Fungsi	=	Menampung Kloroform dari *supplier*
Type	=	Silinder tegak, tutup bawah datar dan tutup atas *torispherical*
Dasar Pemillihan	=	Umum digunakan untuk liquid pada tekanan atmosfer
Kondisi Operasi	=	Tekanan operasi = 1 atm
		Suhu operasi = 30 °C
		Waktu tinggal = 3 hari



Komponen bahan masuk :

Komponen	Berat (kg/jam)	Fraksi berat	ρ (gr/ml)
$CHCl_3$	199,77	0,7143	1,489
H_2O	79,9086758	0,2857	1
Total	279,6803653	1	2,489

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62{,}43 \text{ lb/cuft}$$

$$= \frac{1}{\left(\frac{0{,}71}{1{,}489} + \frac{0{,}286}{1} \right)} \times 62{,}43 \text{ lb/cuft}$$

$$= 81{,}5628 \text{ lb/cuft}$$

Rate Massa = 279,6803653 kg/jam
= 616,5833 lb/jam

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

$$= \frac{616{,}5833 \text{ lb/jam}}{81{,}56 \text{ lb/cuft}}$$

$$= 7{,}5596 \text{ cuft/jam}$$

Direncanakan penyimpanan untuk 14 hari proses

Volume bahan	=	Rate volumetrik x waktu tinggal	
	=	7,5596 x 24 x 14	
	=	2540,0310	cuft

Recycle 80% kloroform

Make-up kloroform	=	2540,031 x (1 - 0,8)	
	=	508,0062	cuft

Purge 1% setiap bulan	=	Volume		x	Persen purge
	=	2540,031	cuft	x	0,01%
	=	0,2540	cuft		
Volume bahan 14 hari	=	Make-up	+		Purge
	=	508,0062	+		0,2540
	=	508,2602	cuft		

$$\text{Volume bahan tiap tangki} = \frac{508{,}2602 \text{ cuft}}{8 \text{ tangki}}$$

$$= 63{,}5325 \text{ cuft}$$

Asumsi bahan mengisi 80% volume tangki, maka :

$$\text{Volume tangki} = \frac{\text{Volume bahan}}{80\%}$$

$$= \frac{63{,}5325}{80\%}$$

$$= 79{,}4157 \text{ cuft}$$

Menentukan dimensi tangki

Asumsi dimensi ratio H/D = 3 **(Ulrich T.4-27)**

H = 3 D

$$\text{Volume silinder} = \frac{\pi}{4} \times D^2 \times H$$

$$= 0{,}785 \times D^2 \times 3 \ D$$

$$= 2{,}355 \ D^3$$

Tutup atas menggunakan torispherical dished, sehingga :

V tutup atas = 0,000049 D^3 (Brownell; pers. 5.11, hal. 88)

jika diambil α = 30 °

$$\text{Volume tangki} = \text{V silinder} + \text{V tutup atas}$$

$$79{,}4157 = 2{,}36 \ D^3 + 0{,}000049 \ D^3$$

$$79{,}4157 = 2{,}3550 \ D^3$$

D^3	=	33,7214		H	=	3 D	
D	=	3,2307	ft		=	9,6922	ft
	=	38,7689	in		=	116,3067	in
	=	0,9847	m		=	2,9542	m

Menentukan tinggi liquid dalam shell

Volume liquid = $\frac{\pi}{4}$ x D² x H

2.540,0310 = 0,785 x 10,4377 x H

2.540,0310 = 8,1936 H

H liq = 310,0025 ft

Menentukan Tekanan Design

P operasi = 1 atm = 14,7 psi

P hidrostatis = ρ x g/gc x H_L

$= 81{,}5628 \ \frac{lbm}{cuft} \times 1 \ \frac{lbf}{lbm} \times 310{,}0025 \ ft$

$= 25284{,}66935 \ \frac{lbf}{ft^2}$

= 175,5880 psi

P design = P operasi + P hidrostatis

= 14,7 + 175,588

= 190,2880 psi

Untuk faktor keamanan, P design dipilih 10% lebih besar

P design = 1,1 x 190,288

= 209,317 psi

Menentukan Ketebalan Dinding Tangki

Tipe material penyusun tangki adalah Stainles Steel. Hal ini disebabkan :

- Mempunyai allowable stress yang besar
- Harga yang relatif lebih murah

Penentuan tebal shell :

$$t_{min} = \frac{P \ X \ ri}{f \ E \ - \ 0{,}6 \ P} + C$$

Dimana :

t_{min} = tebal shell minimum (in)

P = tekanan tangki (psi)

ri = jari-jari tangki (in; 1/2D) =

C = faktor korosi (in: 1/8D) **(Brownell, pg 254)**

E = faktor pengelasan (double welded; 0,8)

f = Stress allowable, bahan konstruksi stainless steel tipe AISI-348, maka f all = 34800 lb/in² **(Perry 7ed; T.28-11)**

Asumsi tebal shell = 1 1/8 in

$$t_{min} = \frac{P \times ri}{f\ E - 0,6\ P} + C$$

$$1\ 1/8 = \frac{209,31678 \times 19,3844}{f \times 0,8 - 0,6 \times 209,3} + 1/8$$

$$1 = \frac{4057,4891}{0,8\ f - 125,5901}$$

$$0,8\ f - 125,59 = 4057,4891$$

$$0,80\ f = 4183,07912$$

$$f = 5228,849 \text{ psi}$$

f hitung lebih kecil dari f *allowable* , jadi tebal shell 1 1/8 memenuhi

Menentukan Tebal Tutup Atas dan Bawah

Tutup atas dan bawah dipilih torispherical

$$OD = ID + 2\ ts$$
$$= 38,769 + 2\ (\ 1\ 1/8\ )$$
$$= 41 \text{ in}$$

Berdasarkan **Tabel 5.7 Brownell** didapatkan :

ts = 7/8
icr = 22 4/5 in
rc = 200 in

$$\frac{icr}{rc} = 11\%$$

karena icr > 6% rc, maka digunakan persamaan 7.76 dan 7.77

Tebal Standart Toripherical Dished (atas)

$$th = \frac{P \times rc \times W}{2\ f\ E - 0,2\ P} + C$$

Dimana:

th = tebal head (in)
W = faktor intensifikasi stress
f = Stress allowable, bahan konstruksi stainless steel tipe AISI-348,
maka f all = 34.800 lb/in² (Perry 7ed; T.28-11)
C = faktor korosi (in) = 1/8 , 10 tahun
(Tabel 6. Timmerhaus, hal.542)
E = faktor pengelasan digunakan double welded E = 0,8
(Tabel 5-7, Brownell, hal.254)
P = tekanan desain

Faktor Intensifikasi stress (W)

$$W = \frac{1}{4} \times \left(3 + \sqrt{\frac{rc}{icr}}\right)$$

$$= \frac{1}{4} \times \quad 3 \quad + \sqrt{\frac{170}{13}}$$

$$= 1{,}4904 \text{ in}$$

Sehingga tebal tutup atas :

Asumsi tebal head = 1 inch

$$th = \frac{P \times rc \times W}{2\ f\ E - 0{,}2\ P} + C$$

$$1 = \frac{209{,}3168 \times 200 \times 1{,}4904}{2 \times f \times 0{,}8 - 0{,}2 \times 209{,}3168} + 1/8$$

$$0{,}88 = \frac{62394{,}6569}{1{,}6\ f - 41{,}8634}$$

$$1{,}4\ f - 37 = 62394{,}6569$$

$$f = 44593{,}777$$

f hitung lebih kecil dari f *allowable* , jadi tebal tutup atas 5/16 memenuhi

Digunakan tebal head standart = 1 in

Tebal botton = tebal head = 1 in

untuk th = 1 in, maka sf = 1,5 - 3

(Tabel 5.6. Brownell, hal.88)

Diambil sf = 2

Menghitung tinggi tutup atas (OA)

$$BC = rc - icr$$

$$= 200 - 22\ 4/5$$

$$= 177 \text{ in}$$

$$AB = \frac{1}{2} Di - icr$$

$$= \frac{1}{2} \times 38{,}769 - 22\ 4/5$$

19,384

$$= -3{,}41556 \text{ in}$$

$$b = rc - (BC^2 - AB^2)^{0,5}$$

$$= 200 - (31400 - 11{,}67)^{0,5}$$

$$= 22{,}83 \text{ in}$$

Jadi, tinggi tutup adalah

$$OA = b + sf + t$$

$$= 22{,}8 + 2 + 1$$

$$= 25{,}8329 \text{ in}$$

$$= 2{,}1527 \text{ ft}$$

untuk tebal tutup bawah datar karena tutup menumpang diatas semen, maka tebal tutup = 1/4 in (Brownell & Young; 58)

Spesifikasi :

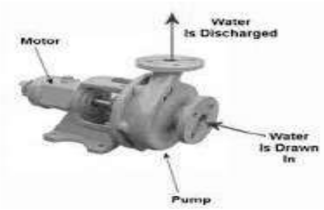
Fungsi	=	Menampung kloroform dari supplier
Type	=	Tangki berbentuk silinder tegak dengan tutup atas berbentuk Torispherical Head dan tutup bawah plate datar
Volume	=	79,4157 cuft
Diameter tangki	=	3,2307 ft
Tinggi tangki	=	9,69222 ft
Tinggi tutup atas	=	2,15 ft
Tebal tangki	=	1 1/8 in
Tebal tutup atas	=	1 in
Tebal tutup bawah	=	1/4 in
Bahan konstruksi	=	Stainless Steel AISI-348
Jumlah	=	8 buah

15 POMPA-3 (L-151)

Fungsi : Mengalirkan kloroform dari tangki penyimpanan ke mixer

Type : Centrifugal pump

Dasar Pemilihan : Sesuai dengan viskositas < 10 cP dan bahan liquid



Rate massa = 279,68 kg/jam

= 616,59 lb/jam

ρ campuran = 81,56 lb/cuft

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

$$= \frac{616{,}5889\ \text{lb/jam}}{81{,}5628\ \text{lb/cuft}}$$

= 7,5597 cuft/jam

= 0,1260 cuft/mnt

= 0,0021 cuft/s

= 0,9426 gpm

Asumsi aliran turbulen

Di optimum untuk aliran turbulen, Nre > 2100, digunakan persamaan :

$Di_{opt} = 3{,}9 \times qf^{0,45} \times \rho^{0,13}$ **(Peters, 4 ed, pers.15 : 496)**

Dengan :

Di opt = diameter optimum ; in

qf = fluid flow rate ; cuft/s

ρ = fluid density ; lb/cuft

$Di_{opt} = 3{,}9 \times 0{,}0624 \times 1{,}7721$

= 0,4311 in

Dipilih pipa 10 in, sch 80 **(Mc Cabe, 5ed, App.5)**

OD = 11 in

ID = 9,6 in = 0,7968 ft = 0,2429 m

$A = 1/4 \times \pi \times ID^2$

= 0,4984 ft²

$$\text{Kecepatan aliran} = \frac{\text{Rate Volumetrik}}{\text{Area Pipa}}$$

$$= \frac{0{,}0021\ \text{cuft/s}}{0{,}49843054\ \text{ft}^2}$$

= 0,0042 ft/s

sg mix = 1,34928571

Viskositas Campuran

T = 30 °C = 303,15 K

$$Log_{10}\,\mu \;= A + \frac{B}{T} + CT + DT^2 \qquad \mu\,Campuran = \sum_{i}^{n} \mu.Xf$$

Data Viskositas Liquid (Yaws, table 22-2)

Komponen	A	B	C	D	µ (cP)
CHCl3	-4,7831	699,02	0,010929	-1,22E-05	**0,513640058**
H2O	-10,2158	1792,5	0,01773	-1,26E-05	**0,815034472**

Komponen	Fraksi berat	µ mix (cP)
CHCl3	0,71428571	0,51364006
H2O	0,28571429	0,81503447
Total	**1**	**1,32867453**

μ mix = 0,000893 lb/ft.s

$$N_{Re} = \frac{D \times v \times \rho}{\mu}$$

$$= \frac{0,7968 \times 0,0042 \times 81,5628}{0,0009}$$

= 307 > 2100 (Asumsi turbulen benar)

Dipilih pipa Commercial stee = 0,000046 m

ε/D = 0,000189

f = 0 **(Geankoplis,3ed,Fig.2.10-3)**

gc = 32,174 ft.lbm/s² lbf

Digunakan persamaan Bernoulli :

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

Perhitungan friksi berdasarkan **Geankoplis 3ed**, Tabel 2.10-1, hal 93

Sambungan / Fitting	Le/D
Elbow standard 90°	35
Gate valve open	9

Panjang ekuivalen suction, Le

Taksiran panjang pipa lurus = 40 ft

2 Elbow 90° = 2 x 32 x 0,7968 = 50,9973 ft

1 Globe valve = 1 x 300 x 0,7968 = 239,05 ft

1 Gate valve = 1 x 7 x 0,7968 = 5,5778 ft

Panjang total pipa (Le) = 335,6252 ft

Friksi yang terjadi :

1 Friksi karena gesekan bahan dalam pipa

$$F_1 = \frac{2f \times v^2 \times L}{gc \times D}$$ **(Peters 4ed, T.1, Hal. 484)**

$$= \frac{2 \times 0{,}004 \times 0{,}0000 \times 335{,}6252}{32{,}174 \times 0{,}7968}$$

$$= 0{,}0000 \text{ ft lbf/lbm}$$

2 Friksi karena kontraksi dari tangki ke pipa

$$F_2 = \frac{K \times v^2}{2 \times \alpha \times gc}$$

$K = 0$ (A tangki >>>A pi **(Peters 4 ed ,hal. 484)**

$\alpha = 1$ (untuk aliran turbulen)

$$F_2 = \frac{0{,}4 \times 0{,}0000}{2 \times 1 \times 32}$$

$$= 0{,}00000 \text{ ft lbf/lbm}$$

3 Friksi karena ekspansi dari pipa ke tangki

$$F_3 = \frac{\Delta v^2}{2 \times \alpha \times gc}$$ (A1 <<< A2, maka v_1 dianggap = 0)

(Geankoplis 3ed, Eq.2.10-16, Hal. 93)

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

$$= \frac{0{,}0000 - 0}{2 \times 1 \times 32}$$

$$= 0{,}0000 \text{ ft lbf/lbm}$$

4 Friksi karena Elbow 90° **(Geankoplis 3ed. 2.10-1 hal 93)**

$$F_4 = K_f \times \frac{v_1^2}{2}$$ **(Geankoplis 3ed, Eq.2.10-16, Hal. 93)**

$$= 3 \times 0{,}8 \times \frac{0{,}0000}{2}$$

$$= 0{,}0000 \text{ ft lbf/lbm}$$

5 Friksi karena Gate Valve

$$F_5 = K_f \times \frac{v_1^2}{2}$$ **(Geankoplis 3ed, T. 2.10-1, Hal. 93)**

$$= 0{,}2 \times \frac{0{,}000018}{2}$$

$$= 0{,}0000 \text{ ft lbf/lbm}$$

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

$$= 0{,}000002 + 1E\text{-}07 + 3E\text{-}07 + 0{,}00002 + 0{,}000002$$

= 2,37E-05 ft lbf/lbm

P_1 = 1 atm + Ph

= 1 atm + ρ x g/gc x h

= (15 x 144) + (81,563 x 1 x 8,1092)

= 2116,8 + 661,41

= 2778,2055 lbf/ft^2

P_2 = 1 atm

= 14,7 lbf/in^2

= 2116,8 lbf/ft^2

$\Delta P = P_2 - P_1$

= 2116,8 - 2778,2

= 661,4055 lbf/ft^2

$$\frac{\Delta P}{\rho} = \frac{661,4055}{81,5628} = 8,1092 \text{ ft lbf/lbm}$$

$$\frac{\Delta v^2}{2 \times \alpha \times gc} = \frac{1,77498E\text{-}05}{2 \times 1 \times 32}$$

= 2,76E-07 ft lbf/lbm

Asumsi : Z_1 = 0,0000 ft

Z_2 = 8,1092 ft

ΔZ = 8,1092 ft

g/gc = 1 lbf/lbm

$$\Delta Z \frac{g}{gc} = 8,1092 \times 1$$

= 8,1092 ft lbf/lbm

Sehingga :

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

= 8,1092 + 8,1092 + 0,0000 + 0,0000

= 16,2183 ft lbf/lbm

$$hP = \frac{-Wf \times \text{flowrate (gpm)} \times sg}{3960}$$

$$= \frac{16,2183 \times 0,9426 \times 1,3493}{3960}$$

= 0,0052 hP

Effisiensi pompa = 30% (Peters 4 ed ; fig 14-37 ; hal 520)

$$BhP = \frac{hP}{\eta\ pompa}$$

$$= \frac{0{,}0052}{30\%}$$

$= 0{,}0$ hP

Effisiensi motor = 84% (Peters 4 ed; fig 14-38 ; hal 521)

$$\text{Power motor} = \frac{\text{BhP}}{\eta \text{ motor}}$$

$$= \frac{0{,}0174}{84\%}$$

$= 0{,}02$ hP

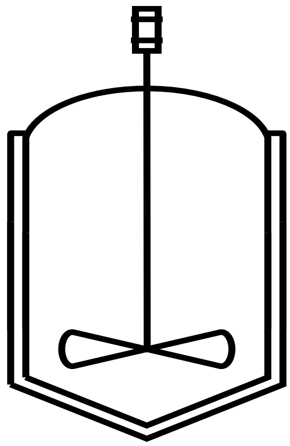
Spesifikasi:

Fungsi	=	Mengalirkan kloroform dari tangki penyimpanan ke mixer
Type	=	Centrifugal pump
Rate volumetrik	=	0,9426 gpm
Total Dynamic He	=	16,218 ft lbf/lbm
BhP	=	0,0174 hP
Power Motor	=	0,0207 hP
Effisiensi pompa	=	30%
Effisiensi motor	=	84%
Bahan konstruksi	=	Commercial steel
Jumlah	=	1 buah

16 Reaktor (210)

Fungsi : Mereaksikan urea dengan asam oleat untuk menghasilkan oleamida

Type Silinder tegal dengan tutup atas torispherical head dan bawah conical dengan dilengkapi pengaduk dan jaket pemanas



Komponen	Massa (kg/jam	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO_2(_l)$	3995.4338	0.9195	0.89
$C_{18}H_{34}O_2(_l)$	211.0343	0.0486	1.32
$CO(NH_2)_2(_l)$	44.9009	0.0103	2.48
$AlCl_3(_s)$	42.2069	0.0097	2.48
$H_2O(_l)$	51.7041	0.0119	1
Totaal	4345.2800	1.0000	7.17

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62.43 \text{ lb/cuf}$$

$$= \frac{1}{\frac{0.9195}{0.8900} + \frac{0.0486}{1.32} + \frac{0.0103}{2.4800} + \frac{0.0103}{2.48} + \frac{0.0097}{2.48} + \frac{0.0119}{1}}$$

x 62.43 lb/cuft

= 57.8989 lb/cuft

Rate Massa = 4345.28 kg/jam

= 9579.6 lb/jam

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

= $\frac{9579.6 \text{ lb/jam}}{57.90 \text{ lb/cuft}}$

= 165.4540 cuft/jam

Asumsi bahan mengisi 80% volume tangki, maka :

Volume tangki = $\frac{\text{Volume}}{80\%}$ x waktu tinggal

= $\frac{165.4540}{80\%}$ x 2

= 413.6350 cuft

A Menentukan dimensi tangki

Asumsi dimensi ratio = 2 **(Ulrich T.4-27)**

H = 2 D

Volume silinder = $\frac{\pi}{4}$ x D² x H

= 0.785 x D² x 2 D

= 1.57 D³

Tutup atas dan bawah menggunakan torispherical dished, sehingga :

V tutup atas = 4.9E-05 D³ (Brownell; pers. 5.11, hal. 88)

V tutup bawah = 4.9E-05 D³

jika diambil α = 30 °

Volume tangki = V silinder + V tutup atas + V tutup bawah

413.6350 = 1.57 D³ + 4.9E-05 D³ + 4.9E-05 D³

413.6350 = 1.5701 D³

D³ = 263.4453   H = 2 D

D = 6.4106 ft   = 12.82115 ft

= 76.9269 in   = 153.854 in

= 1.9539 m   = 3.90789 m

Menentukan tinggi liquid dalam shell

Volume liquid = $\frac{\pi}{4}$ x D² x H

165.4540 = 0.785 x 41.0954 x H

165.4540 = 32.2599 H

H liq = 5.1288 ft

Menentukan Tinggi Tuup Bawah (Conical)

h = $\frac{\text{tg } \alpha \text{ x } (D - m)}{2}$ **(Hesse, pers 4-17)**

Dengan α = sudut coni = 120 ° 1/2α = # °
D = diameter tan((ft)
m = flat sport diame = 12 in = 1 ft

$$h = \frac{tg\ \alpha \times (D - m)}{2}$$

$$h = \frac{tg\ 120 \times (6.4106 - 1)}{2}$$

h = 4.6857 ft
= 1.4282 m

Menentukan volume conical

volume conical = 0,262 ×H ×(D²+D.m+m²)
= 0.262 x 4.6857 x 48.51
= 59.5485 cuft

Menentukan Tekanan Design

P opera = 1 atm = 15 psi

P hidrosta = ρ x g/gc x H_L

$$= 57.90\ \frac{lbm}{cuft} \times 1\ \frac{lbf}{lbm} \times 5.1288\ ft$$

$$= 296.951\ \frac{lbf}{ft^2}$$

= 2.0622 psi

P design = P opera + P hidrostatis
= 14.7 + 2.0622
= 16.7622 psi

Untuk faktor keamanan, P design dipilih 10% lebih besar

P design = 1.1 x 16.7622
= 18.44 psi

Menentukan ketebalan dinding Reaktor

Penentuan tebal shell :

$$t_{min} = \frac{P \times ri}{f\ E - 0.6\ P} + C$$

Dimana :

t_{min} = tebal shell mini (in)
P = tekanan tangki (psi)
ri = jari-jari tangki (in; 1/2 =
C = faktor korosi (in: 1/8D) **(Brownell, pg 254)**
E = faktor pengelas (double weld 0.8)
f = Stress allowable, bahan konstruksi Carbon steel SA 167 Grade C,
maka f all = 18,750 psi **(Brownell, T.13.1 hal.251)**

Asumsi tebal sh = 0.2 in

$$t_{min} = \frac{P \times ri}{f\ E - 0.6\ P} + C$$

$$3/16 = \frac{18.44 \times 38.4634}{f \times 0.8 - 0.6 \times 18} + 1/8$$

$$1/16 = \frac{709.2032}{0.8\ f - 11.06}$$

0.1 f - 0.6914 = 709.2

0.05 f = 709.8946

f = 14197.9 psi

f hitung lebih kecil dari f *allowable* , jadi tebal shell 1/4 memenuhi

Menentukan Tebal Tutup Atas

Tutup atas dan bawah dipilih torispherical

OD = ID + 2 ts

= 76.927 + 2 (3/16)

= 77 in

Berdasarkan **Tabel 5.7 Brownell** didapatkan :

ts = 3/16

icr = 2.63 in

rc = 42 in

$$\frac{icr}{rc} = 6.25\%$$

karena icr > 6% rc, maka digunakan persamaan 7.76 dan 7.77

Tebal Tutup Atas (Torispherical Dished)

$$th = \frac{P \times rc \times W}{2\ f\ E - 0{,}2\ P} + C$$

Dimana:

th = tebal head (in)

W = faktor intensifikasi stress

f = Stress allowable, bahan konstruksi stainless steel tipe AISI-348,
maka f all = 34800 psi **(Brownell, T.13.1 hal.251)**

C = faktor korosi (ir = 1/8 , 10 tahun
(Tabel 6. Timmerhaus, hal.542)

E = faktor pengelasan digunakan doub E = 0.8
(Tabel 5-7, Brownell, hal.254)

P = tekanan desain

Faktor Intensifikasi stress (W)

$$W = \frac{1}{4} \times \left(3 + \sqrt{\frac{rc}{icr}}\right)$$

$$= \frac{1}{4} \times \quad 3 + \sqrt{\frac{72}{4\ 3/8}}$$

$$= 1.7500 \text{ in}$$

Sehingga tebal tutup atas :

Asumsi tebal he = 1/5

$$th = \frac{P \times rc \times W}{2\ f\ E - 0{,}2\ P} + C$$

$$3/16 = \frac{14.7 \times 42 \times 1.7500}{2 \times f \times 0.8 - 0.2 \times 14.7} + 1/8$$

$$0.06 = \frac{1080.4500}{1.6\ f - 2.9400}$$

$$0.1\ f - 0 = 1080.45$$

$$f = 10806.3$$

f hitung lebih kecil dari f *allowable* , jadi tebal tutup atas 3/16 memenuhi

Digunakan tebal head s = 3/16 in

Tebal bott = tebal he = 3/16 in

untuk tl = 3/16 in, maka sf = 1,5 - 2

(Tabel 5.6. Brownell, hal.88)

Diambil sf = 2

Menghitung tinggi tutup atas (OA)

$$BC = rc - icr$$
$$= 42 - 2.6$$
$$= 39 \text{ in}$$

$$AB = \frac{1}{2} Di - icr$$
$$= \frac{1}{2} \times 76.927 - 2.6$$
$$= 35.84 \text{ in}$$

$$b = rc - (BC^2 - AB^2)^{0,5}$$
$$= 42 - (1550 - 1284)^{0,5}$$
$$= 26 \text{ in}$$

Jadi, tinggi tutup adalah

$$OA = b + sf + t$$
$$= 26 + 2 + 3/16$$
$$= 27.878 \text{ in}$$

= 2.3232 ft
= 0.708 m

Tinggi reaktor t = Hs + Hta + Htb
= 12.82 + 2.3232 + 4.6857
= 19.83 ft
= 6.0442 m

Tebal Tutup Bawah (Conical)

Sudut con = 60 °

e = 0.8

$$th = \frac{P \times Di}{\cos \alpha\ (f\,E - 0{,}6\ \text{]}} + C$$

$$3/16 = \frac{18.4 \times 76.9269}{2\ \cos 60\ (\ f \times 0.8 - 0.6 \times 18.4\ )} + 1/8$$

$$1/16 = \frac{1418.40636}{1\ ((\ f\ \ 0.8\ ) - (\ 11.06\ )}$$

$$1/16 = \frac{1418.4064}{0.8000\ f - 11.06}$$

0.05 f - 0.6914 = 1418.41

0.05 f = 1417.71

f = 28354.3 psi

f hitung lebih kecil dari f *allowable* , jadi tebal shell 3/16 memenuhi

B. Desain Sistem Pengaduk

Jumlah Baffl = 4

Jumlah Impeller (pengaduk) antara 4 - 16, tetapi umumnya 6 atau 8

Dipilih pengaduk type flat blade turbine dengan jumlah blade 6

Penentuan Dimensi Pengaduk

Tinggi bahan total = 5.1288 ft = 61.545 in

Diameter dalam D = 6.4106 ft = 76.9269 in

Ukuran pengaduk diambil dari **MC.cabe ed 7th, hal.247**

$$\frac{Da}{Dt} = \frac{1}{3} \qquad \frac{E}{Dt} = \frac{1}{3} \qquad \frac{W}{Da} = \frac{1}{5}$$

$$\frac{L}{Da} = \frac{1}{4} \qquad \frac{J}{Dt} = \frac{1}{12} \qquad \frac{H}{Dt} = 1$$

$\text{Offset 1} = \frac{1}{2} Da$ $\quad \text{Offset 2} = \frac{1}{6} J$ **Wallas,hal 288: 199(**

Keterangan :

Da = Diameter impeller (pengaduk)
Dt = Diameter tangki
L = Panjang blade
W = Lebar blade
E = Jarak impeller (pengaduk) dari dasar tangki
J = Lebar baffle
Offset 1 = Jarak baffle dari dasar tangki
Offset 2 = jarak baffle dari permukaan cairan

Diameter impeller (Da) = 1/3 = 1/3 x 6.4106
= 2.1369 ft
Lebar blade (W) = 1/5 Da = 1/5 x 2.1369
= 0.4274 ft
Panjang blade (L)= 1/4 Da = 1/4 x 2.1369
= 0.5342 ft
Jarak impeller dari dasar (E) = 1/3 x 6.4106
= 2.1369 ft
Lebar baffle (J) = 1/12 Dt = 1/12 x 6.4106
= 0.5342 ft
Tebal pengaduk = 1/10 x 0.5342
= 0.0534 ft
Offset 1 = 1/2 Da = 1/2 x 2.1369
= 1.0684 ft
Offset 2 = 1/6 J = 1/6 x 0.5342
= 0.0890 ft
Panjang baff = H_l - (Offset 1 + Offset 2)
= 5.1288 - (1.0684 + 0.0890)
= 3.9713 ft

Penentuan Jumlah Pengaduk

Sg = ∑Fraksi bahan x ρ bahan
Sg = 0.9322

$$\text{Jumlah Impeller} = \frac{\text{tinggi liquid x sg}}{\text{Diameter tangki}}$$

$$= \frac{5.1288 \times 0.9322}{6.4106}$$

$$= 0.7458 \approx 1 \text{ buah}$$

Jarak Pengaduk = 1.5 x Da
= 1.5 x 2.1369
= 3.2053 ≈ 3 buah

Penentuan Power Motor

Viskositas Campuran

T = 30 °C = 303.2 K

$$Log_{10}\,\mu = A + \frac{B}{T} + CT + DT^2 \qquad \mu\ Campuran = \sum_{i}^{n} \mu . Xf$$

Data Viskositas Liquid (Yaws, table 22-2)

Komponen	A	B	C	D	μ (cP)
C18H34O2(l	-6.1303	1689.3	0.008372	-6.45E-06	**1.260185177**
CO(NH2)2	-1.7534	842.39	-8.24E-13	5.47E-16	**10.60203852**
H2O	-10.2158	1792.5	0.01773	-1.26E-05	**0.815034472**
C18H35NO(	-5.475	1564.3	0.00843	-6.9E-06	**1.572672382**

Komponen	Fraksi berat	μ mix (cP)
C18H34O2(	0.0486	0.0612
CO(NH2)2	0.0103	0.1096
H2O	0.0097	0.0079
C18H35NO	0.9195	1.4461
Total	**0.9881**	**1.6247**

μ liq mix = 0.00109 lb/ft.s

Perhitungan Viskositas Slurry

$$\mu_m = \mu_L[1 + 2.5\Phi + 10.05\Phi^2 + 0.00273\ \exp(16.6\Phi)]$$

μr = Viskositas slurry campuran (cp) **(Menon S.E, hal. 606)**

μI = Viskositas liquid (cp)

ϕ = Fraksi slurry = 1.61 % = 0.01615

% solid = 1 % % liquid = 99.03 %

ρ solid = 2.48 ρ liquid = 4.15

Sg mix = 4.12

Cv = 1.615 %

μm = 1.6247 [1 + 2.5 x 0.0161 + 10.05 x 0.0003 + 0.00273

exp (16.6 x 0.0161)

= 1.70038 cp

Jadi μ mix = 0.001143 lb/ft.s

V = π x Da x N **(Joshi, hal.389)**

Dimana :

V = Peripheral speed; m/mnt

Untuk pengaduk jenis turb 200 - 250 m/mnt

Da = Diameter impeller = 2.1369 ft = 0.6513 m

N = Putaran pengaduk; rpm

Dipilih putaran peng N = 200 rpm = 3.33 rps

V = π x Da x N

= 3.1 x 0.6513 x 200

= 409.0253 m/meni **(memenuhi range 200-250 m/menit)**

Bilangan Reynold, Nre :

$$Nre = \frac{\rho \times Da^2 \times N}{\mu}$$

$$Nre = \frac{57.899 \times 4.5662 \times 3.33}{0.001143}$$

$$= 771233.8 > 2100$$

Untuk NRe > 2100 diperlukan 4 buah baffle sudut 90°

(Perrt 8ed : 18-13)

Power pengaduk :

Untuk NRe > 10.000 perhitungan power menggunakan persamaan berikut

$$P = \frac{Kt}{g} \times \rho \times N^3 \times Da^5$$ **udwig, vol-1, pers 5.5, hal 2!**

Keterangan :

P = power ; ft.lb/s

Kt = faktor mixer (tu ; 6.3 **(Ludwig, vol-1, T.5-1, hal 301)**

g = faktor konversi ; 32.2 lbm.ft/lbf/s²

ρ = densitas ; lb/cuft

N = kec.putaran imp ; rps

Da = diameter impell ; ft

$$P = \frac{Kt}{g} \times \rho \times N^3 \times Da^5$$

$$= \frac{6.3}{32} \times 57.9 \times 37.04 \times 44.5531$$

$$= 18692.6 \text{ lb.ft/s}$$

$$Hp = \frac{P}{550}$$ **dwig, vol-1, Pers.5-6, hal**

$$= \frac{18692.6}{550}$$

$$= 33.9865 \text{ hP}$$

Untuk 2 buah impeller, maka pow = jumlah impeller x hP

= 1 x 33.9865

= 33.99 hP

Perhitungan losses pengaduk

Gland losses (Kebocoran tenaga akibat poros = 10%

Gland losses 10% = 10% x 33.99

= 3.3986 hP

Power input dengan gland lo = 33.99 + 3.3986

= 37.3851 hP

Transmission system losse = 20% (Joshi : 424)

= 20% x 37.3851

= 7.4770 hP

Power input dengan transmission sys = 37.3851 + 7.4770

= 44.86 hP

Effisiensi moto = 80%

Sehingga power motor $= \dfrac{44.8622}{80\%}$

= 56.078 hP ≈ 56 hP

C. Sistem Pendingin

Perhitungan jaket pendingin

Sebagai media pendingin dengan suhu = 30 °C

Untuk menjaga suhu supaya suhu dalam n = 30 °C

Q serap = 5E+05 kkal.jam

Suhu bahan masul = 75 °C = 167 °F

Suhu bahan kelua = 35 °C = 95 °F

Suhu pendingin m = 30 °C = 86 °F

Suhu pendingin kel = 45 °C = 113 °F

$\Delta t1$ = 167 °F - 86 °F = 81 °F

$\Delta t2$ = 113 °F - 95 °F = 18 °F

$$\Delta T\ LMTD = \frac{\Delta t2 - \Delta t1}{2.3 \log \dfrac{\Delta t2}{\Delta t1}}$$

$$= \frac{18 - 81}{2.3 \log \dfrac{18}{81}}$$

$$= \frac{-63}{-1.502}$$

$$= 41.9332\ °F$$

Temperatur kalorik

$$Tc = \frac{\text{Suhu bahan masul} + \text{Suhu bahan keluar}}{2}$$

$= \dfrac{167 \quad + \quad 95}{2}$

$= 131$ °F

tc = $\dfrac{\text{Suhu steam ma} + \text{Suhu steam keluar}}{2}$

$= \dfrac{86 \quad + \quad 113}{2}$

$= 99.5$ °F

ρ air = 62.16 lb/cuft

Rate Volumetrik = $\dfrac{\text{Kebutuhan Cooling Water}}{\rho \text{ steam}}$

$= \dfrac{6,856}{62.16}$

= 110 cuft/jam

= 0.0306 cuft/s

Koefisien Perpindahan Panas bagian luar jaket :

hi = 0.4 (k/Di) $\left[\dfrac{L^2 \; N \rho}{\mu}\right] \left[\dfrac{C \mu}{k}\right]^{1} \left[\dfrac{\mu}{\mu_w}\right]^{0,14}$

Keterangan : **(Kern page.718 eq. 20-1)**

Di = Diameter tangki

L = Da (diameter impe = 2.1369 ft

N = Putaran Pengaduk = 200 rpm = 12,000 rph

ρ = Berat jenis larutan = 57.8989 lb/cuft

μ = Viskositas la = 0.00114 lb/ft.s

= 4.11355 lb/ft.jam

= 1.70054 cP

C = Kapasitas panas campuran

Komponen	Fraksi (Xf)	Cp (kJ/kg K)
$C_{18}H_{34}O_2$	0.9195	2.100
$CO(NH_2)_2$	0.0486	2.460
$AlCl_3$	0.0103	1.000
H_2O	0.0097	4.330
Subtotal	1.0000	

1 kJ/kg = 0.23885 Btu/lb°F

C = %Cp1 + %Cp2 + %Cp3 +…...+%Cpn

= 0.5022 Btu/lb°F

K = Konduktifitas larutan

$$Kmi = \frac{0.0677}{sg\,[\ 1 - 3E\text{-}04\ (\ \Delta T\,LM - 32\ )\ ]}$$

$$= \frac{0.0677}{0.9322\ [\ 1 - 3E\text{-}04\ (\ 41.9332 - 32\ )\ ]}$$

$$= 0.07284 \ \ \text{Btu/jam.ft.°F}$$

$$Re\ p = \frac{[\ L^2\ N\,\rho]}{\mu}^{2/3}$$

$$= \left(\frac{4.57 \times 12000 \times 200}{0.0011}\right)^{2/3}$$

$$= 4,514,041$$

$$\frac{[C\,\mu\,]}{k}^{1} = \left(\frac{0.502 \times 0.0011}{0.072843505}\right)^{1/3}$$

$$= 0.1990$$

$$\frac{[\,\mu\,]}{\mu_w}^{0,14} = \frac{[\ 4.114\ ]^{0,14}}{1}$$

$$= 1.21896$$

$$hi = 0.4 \times \frac{0.073}{6.4106} \times 4514041 \times 0.1990 \times 1.21896$$

$$= 4478.83 \ \ \text{Btu/jam ft}^2\ °\text{F}$$

Koefisien perpindahan panas bagian dalam jaket
bejana :
Dari Kern tabel 10, dipakai pipa 16 BWG dengan ukuran :
OD = 1.5 in **(Kern, Tabel 10 hal.843)**
ID = 1.4 in
A (flow area) = 1.47 in = 0.0009484 m^2
Surface per lin ft (= 0.3925 ft^2

$$v = \frac{W}{\rho \times A} = \frac{6855.8105}{\rho \times A}$$

$$= \frac{6855.8105}{1000\ \ kg/m^3 \times 0.000948\ \ m^2}$$

$$= 7228.93 \ \ \text{m/jam}$$

$$= 120.482 \ \ \text{m/s}$$

$$= 395.283 \ \ \text{ft/s}$$

hi = 310 Btu/jam.ft^2.°F **(Kern, Fig.25 hal.835)**

hio $= hi \times \dfrac{ID}{OD}$

$= 310 \times \dfrac{1.37}{1.5}$

= 283.1 Btu/jam.ft^2.°F

$Uc = \dfrac{hi \times hio}{hi + hio}$

$= \dfrac{310 \times 283}{310 + 283}$

= 147.9791

Rd = 0.001 **(Kern tabel 12 pg. 845)**

$\dfrac{1}{Ud} = \dfrac{1}{Uc} + Rd$

$\dfrac{1}{Ud} = \dfrac{1}{147.9791} + 0.001$

$\dfrac{1}{Ud} = 0.0078$

Ud = 128.9 Btu/jam ft² °F

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

$= \dfrac{515267.8674}{128.9 \times 41.9332}$

= 95 ft²

Mentukan Tinggi jaket

Tinggi Jak = Tinggi tangki + Tinggi tutup bawah

= 12.8211 + 4.6857

= 17.5068 ft

Asumsi :

Tebal jaket (tj) = 1/5 in

Tebal air pendingin (s) = 5 in

Effisiensi sambungan la = 0.8

Faktor korosi = 1/8

Bahan konstruksi = Carbon steel SA 167 Grade C

f all = 18750 psi

Do (Shell) = Di + 2 ts

= 76.93 + 2 (1/5)

= 77.3 in
= 6.442 ft

Di (jaket) = Do (Shell) + 2 s
= 77.3 + 2 (5)
= 87.3 in
= 7.275 ft

Do (jaket) = Di (jaket) + 2 tj
= 87.3 + 2 (1/5)
= 87.68 in
= 7.3064 ft

Penentuan tebal jaket

P hidrosta = ρ x g/gc x h liq

$= 62.16 \dfrac{lbm}{cuft} \times 1 \dfrac{lbf}{lbm} \times 5.1288 \text{ ft}$

$= 318.8049 \dfrac{lbf}{ft^2}$

= 2.2139 psi

P jaket = (Pi - Po)jaket
= 18.4384 - 14.7
= 3.7384 psi

P design = P jaket + P hidrostatis
= 3.7384 + 2.2139
= 5.9523 psi

Tebal jaket berdasarkan ASME Code untuk cylindrical tank

$$t\ min = \frac{P \times Dij}{2fE - P} + C$$

$$3/16 = \frac{5.9523 \times 87.3019}{2 \times f \times 0.8 - 5.9523} + 1/8$$

$$1/16 = \frac{519.6465}{1.6\ f - 5.9523}$$

0.1 f - 0.3720 = 519.6465
0.1 f = 520.0186
f = 5200.1856 psi

f all > f design
18750 > 5200.19

Maka, digunakan tj = 1/5 in

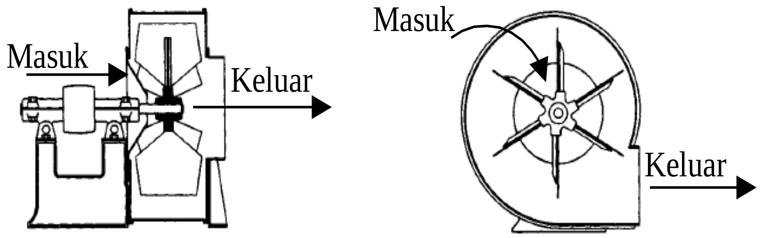
Spesifikasi :

Fungsi	=	Mereaksikan urea dan asam oleat membentuk oleamida
Type	=	Silinder tegal dengan tutup atas torispherical head dan bawah conical dengan dilengkapi pengaduk dan jaket pemanas
Bahan konstruk	=	Stainless Steel
Kapasitas	=	165.5 cuft
Jumlah	=	1 buah
Dimensi Shell		
Diameter shell	=	6.4106
Tinggi shell	=	12.82
Tebal shell	=	3/16
Dimensi Tutup		
Tebal tutup atas	=	3/16
Tinggi tutup ata	=	2.3232
Tebal tutup baw	=	1/5
Tinggi tutup ba	=	4.6857
Sistem Pengaduk		
Jenis	=	Tipe flat blade turbin dengan jumlah blade 6 buah
Jumlah impeller	=	1
Diameter impel	=	2.1369 ft
Lebar blade	=	0.4274 ft
Panjang blade	=	0.5342 ft
Jarak impeller	=	2.1369 ft
Lebar baffle	=	0.5342 ft
Putaran	=	200 rpm
Power motor	=	56 hP
Jaket Pendingin		
Tinggi jacket	=	17.5068 ft
Tebal jacket	=	1/5 in
Diameter jaket	=	7.3064 ft

ι

17. BLOWER-1 (G-211)

Fungsi : Untuk menghembuskan CO_2 dan NH_3 menuju cooler



Komposisi bahan masuk :

Komponen	Berat (Kg/jam)	Fraksi berat	ρ (gr/ml) **Perry 7ed**	fraksi/ρ
CO_2 (g)	625.6195258	0.72131148	0.5971	1.208025
NH_3 (g)	241.716635	0.27868852	1.56	0.178646
Total	867.3361608	1	2.1571	1.386671

$$\rho \text{ mix} = \frac{1}{\Sigma \dfrac{\text{Fraksi Berat Komponen}}{\rho \text{ komponen}}} \times 62.43 \quad \frac{\text{lb/ft}^3}{\text{g/cm}^3}$$

$$= \frac{1}{1.386671068} \times 62.43$$

$$= 45.02149172 \text{ lb/ft}^3$$

Rate massa = 867.336161 kg/jam
= 1912.14665 lb/jam

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

$$= \frac{1912.14665}{45.0214917}$$

= 42.4718634 cuft/jam
= 0.70786439 cuft/menit

Digunakan multiple stage blower

Menentukan dimensi blower :

Asumsi Aliran turbulen

Dipilih pipa 12 in, sch 40 **[Foust, App.C6a]**

OD = 12.75

ID = 11.938

$A = 1/4 \times \pi \times ID^2$

$= 1/4 \times 3.1 \times 143$

$= 111.8749 \text{ in}^2$

Perhitungan power blower:

HP = 0.000157 x Q x ΔP **(Perry ed 7 ; pers. 10-88 ; pg. 10-46)**

Pressure drop diambil = 0.5 psi

Dimana:

1 psi = 27.7 in H_2O

0.5 psi = 13.9 in H_2O

HP = 0.000157 x Q x ΔP

= 0.000157 x 0.708 x 13.9

= 0.00154477 HP

$$\text{Efisiensi} = \frac{\text{HP blower}}{\text{HP shaft}}$$ **(Perry ed 7 ; pers. 10-89 ; pg. 10-46)**

Efisiensi blower = 40% - 80% **(Perry ed 7; pg. 10-46)**

Dipilih efisiensi blower = 80%

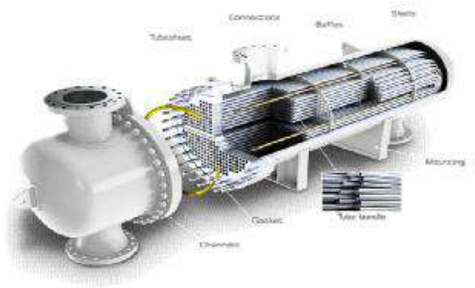
$$\text{HP shaft} = \frac{\text{HP blower}}{\text{Efisiensi}} = \frac{0.00154477}{80\%} = 0.00193097 \text{ HP}$$

Spesifikasi:

Fungsi	=	Untuk menghembuskan CO_2 dan NH_3 menuju cooler
Type	=	Centrifugal blower
Dasar pemilihan	=	sesuai dengan jenis bahan dan efisiensi tinggi
Rate volumetrik	=	42.472 cuft/jam
Efisiensi blower	=	80%
Power	=	0.0019 HP
Bahan konstruksi	=	Carbon steel
Jumlah	=	1 buah multistage

18. COOLER-1 (E-212)

Fungsi : Mendinginkan gas NH_3 dan CO_2 keluaran reaktor



bahan masuk :

Komponen	Berat (kg/jam)
$NH_{3\,(g)}$	241.716635
$CO_{2\,(g)}$	625.619526
Total	867.336161

Berat bahan masuk	=	867.336161	kg/jam
	=	1912.14665	lb/jam
Q Serap	=	36421.5069	Kkal/jam
	=	144447.696	Btu/jam
Kebutuhan air pendingin	=	2426.36072	kg/jam
	=	5349.20336	lb/jam

<u>Perhitungan ΔT LMTD</u>

Fluida dingin

Temperatur air						
t1	=	30	°C	=	86	°F
t2	=	45	°C	=	113	°F

Fluida panas

Temperatur gas						
T1	=	160	°C	=	320	°F
T2	=	35	°C	=	95	°F

$\Delta t_1 = T_2 - t_1 = 320 - 113 = 207$ °F

$\Delta t_2 = T_1 - t_2 = 95 - 86 = 9$ °F

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

(Kern; Pers. 5.14; Hal. 89)

$$= \frac{9 - 207}{\ln \frac{9}{207}}$$

$= 63.14794$ °F

$$R = \frac{T_1 - T_2}{t_2 - t_1} = \frac{320 - 95}{113 - 86} = 8$$

$$S = \frac{t_2 - t_1}{T_1 - t_1} = \frac{113 - 86}{320 - 86} = 0.1154$$

(Kern; Pers. 5.14; Hal. 149)

F_T = 0.87 **(Kern; Fig. 18; Hal. 828)**

ΔT LMTD = ΔT LMTD x F_T

= 54.9387076

Temperatur rata-rata

$t_c = t_{av}$ air pendingin

$$= \frac{86 + 113}{2}$$

= 99.5 °F

$T_c = T_{av}$ gas

$$= \frac{320 + 95}{2}$$

= 207.5 °F

Trial Ukuran Heater (Kern. Pg :229)

a. Trial Ud = 250 Btu/hr.ft². °F **(Kern T.8, Pg : 840)**

$$A = \frac{Q}{UD \times \Delta T\ LMTD}$$ **(Kern; Pers. 7.6; Hal. 140)**

$$= \frac{144447.6964}{250 \times 54.93871}$$

= 10.5170072 ft²

Berdasarkan Kern tabel 9 & 10 maka dipilih :

Tube Side

OD	=	1	in
BWG	=	18	
Wall thickness	=	0.049	in
ID	=	0.902	in
Passes	=	2	
a't	=	0.639	in²
a"	=	0.2618	ft²/ft.panjang
Pitch	=	1 1/4	in
Panjang tube	=	4	ft

Shell Side

Passes	=	1	
ID	=	21 1/4	in

$$N_t = \frac{A}{L \times a''} = \frac{10.51700723}{4 \times 0.2618} = 10.0430$$

Nt distandarkan dan IDs didapatkan dari **tabel 9 Kern**
Diketahui Nt 354,69; 2 passes; 3/4in.OD on 1-in square pitch
Maka diperoleh : Nt standar = 398
ID shell = 21 1/4

A baru = Nt standar x Panjang tube x a''
= 398 x 4 x 0.2618
= 416.7856 ft²

$$UD \text{ baru} = \frac{Q}{Abaru \times \Delta T\ LMTD} = \frac{144447.6964}{416.7856 \times 54.9387076} = 6.3084 \text{ Btu/hr.ft}^2.\ {}^\circ F$$

Baffle spacing = $\frac{\text{ID Shell}}{5}$ **(Kern pers 11.4; Pg.226)**
= 4.25 in

Fluida Dingin (Tube Side)	**Fluida Panas (Shell Side)**
Air	**Gas NH_3 dan CO_2**
1) Flow area (at)	**1) Flow area**
at = $\frac{Nt \times a't}{144 \times n}$	C'' = Pt - OD
= $\frac{398 \times 0.639}{144 \times 2}$	= 1 - 1
= 0.8831 ft²	= 1/4 in
	B = 4 1/4 in
	as = ID x C'' x B / 144 Pr
	= $\frac{21 \times 1/4 \times 4.3}{144 \times 1\ 1/4}$
	= 0.1254 ft²
2) Mass Velocity (Gt)	**2) Mass Velocity (Gs)**
Gt = $\frac{w}{at}$	Gs = $\frac{w}{as}$
= $\frac{5349.20336}{0.8831}$	= $\frac{1912.14665}{0.1254}$
= 6057.55919 lb/jam.ft2	= 15244.2418 lb/jam.ft2

3) Pada tc = 99.5 °F

μ = 0.75 cps **(fig.15)**
= 1.815 lbm/jam.ft

$Di = \frac{0.9}{12}$
= 0.0752 ft

$Ret = \frac{D \times Gt}{\mu}$
$= \frac{0.0752 \times 6058}{1.8150}$
= 250.8686

4) jH = 78 (fig.24)

5) Pada tc = 99.5 °F

k = 0.362 Btu/hr.ft²(°F/ft)
(Kern T.5, Pg:800)

Cp = 0.98 Btu/lb.°F
(Kern, F.2, Pg:804)

$\left(\frac{Cp.\mu}{k}\right)^{1/3} = 1.7001$

6) $\frac{hi}{Øt} = jH \times \frac{k}{D} \times \left(\frac{Cp \times \mu}{k}\right)^{1/3}$
$= 78 \times \frac{0.362}{0.0752} \times 1.7001$
= 638.6201

7) $\frac{hio}{Øt} = \frac{hi}{Øs} \times \frac{ID}{OD}$
$= 638.6201 \times \frac{21\ 1/4}{1}$
= 13570.68

8) $tw = tc + \frac{hi/Øt \times (Tc - tc)}{hio/Øs + hi/Øt}$
$= 100 + \frac{13571 \times 108}{361.43 + 13571}$
= 204.6982 °F

μw = 0.2 Cp
= 0.484 lb/ft.hr

3) Pada Tc = 207.5 °F

μ = 0.0532 cps **(fig.15)**
= 0.1287 lbm/jam.ft

$De = \frac{0.95}{12}$ **(fig.28)**
= 0.0792 ft

$Res = \frac{D \times Gs}{\mu}$
$= \frac{0.0792 \times 15244}{0.1287}$
= 9373.919

4) jH = 430 (fig.28)

5) Pada Tc = 207.5 °F

k = 0.0533 Btu/hr.ft²(°F/ft)
(Kern T.5, Pg:801)

Cp = 0.805 Btu/lb.°F
(Kern, F.3, Pg:805)

$\left(\frac{Cp.\mu}{k}\right)^{1/3} = 1.248$

6) $\frac{hi}{Øs} = j_H \times \frac{k}{D} \times \left(\frac{Cp \times \mu}{k}\right)$
$= 430 \times \frac{0.0533}{0.079} \times 1.2$
= 361.4325

7) $tw = Tc + \frac{hi/Øs \times (Tc - tc)}{hio/Øt + ho/Øs}$
$= 208 + \frac{361.43 \times 108}{13571 + 361.43}$
= 210.3 °F

8) μw = 0.060 cP
= 0.145 lb/ft.hr

$Øt = \left(\frac{\mu}{\mu w}\right)^{0,14}$
$= \left(\frac{0.1287}{0.145}\right)^{0.14}$
= 0.9833

$Øs = \left(\frac{\mu}{\mu w}\right)^{0,14}$ $= \left(\frac{1.815}{0.484}\right)^{0.14}$ $= 1.2033$ 9) Faktor koreksi hio $hio = \frac{hio/Øt}{Øt}$ $= 16329.24$	

12. Clean overall coefficient, Uc :

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

$$= \frac{361.43 \times 16329}{361.43 + 16329}$$

$$= 353.6057 \text{ Btu/hr ft}^2\ °F$$

13. Dirt factor, Rd :

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

$$= \frac{353.61 - 6.3084}{353.61 \times 6.3084}$$

$$= 0.156$$

Rd perhitungan > Rd data **(Kern T 12 Hal 845)**

0.156 >= 0.002 untuk media air

(memenuhi, karena Rd hitung > Rd allowable)

Fluida Dingin (Tube Side)	Fluida Panas (Shell Side)
Air	**Gas NH3 dan CO2**
Pressure Drop	
a. Untuk Ret : 250.868613 f = 0.00025 ft²/in² **(Kern, fig 26 hal 836)** specific volume of steam : **(Kern,T 7 Hal 816)** v = 6.655 ft³/lb $s = \frac{0.1503}{62.5}$ = 0.0024	**a'. Untuk Res :** 9373.91884 f = 0.0015 ft²/in² **(Kern, fig 29 hal 839)** s = 0.59
b. $\Delta Pt = \frac{1}{2} \times \frac{f \times Gt^2 \times L \times n}{5{,}22 \times 10^{10} D.\ s.\varphi t}$ = 0.0038898 ΔPt < 10 psi (Memenuhi untuk air)	**b'.** No of crosses $N + 1 = \frac{12\ L}{B}$ = 11.29412

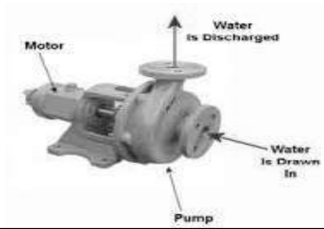
	c'. ΔPs $= \dfrac{f \times Gs^2 \times De \times (N + 1)}{5{,}22 \times 10^{10} \times De \times s \times \varphi s}$ = 0.000 psi $\Delta Ps < 2$ psi (Memenuhi untuk gas)

Spesifikasi :

Fungsi	=	Mendinginkan gas NH_3 dan CO_2 keluaran reaktor	
Type	=	Shell and tube, 1-2 exchanger	
Tube			
Inside Diameter	=	1	in
Outside Diameter	=	1	in
Panjang	=	4	ft
Pitch	=	1.25	in
Jumlah Tube	=	398	buah
Passes	=	2	
BWG	=	18	BWG
Shell			
Inside Diameter	=	21.25	in
Passes	=	1	

19 POMPA-4 (L-213)

Fungsi : Mengalirkan campuran oleamida dari reaktor ke cooler
Type : Centrifugal pump
Dasar Pemiliha : Sesuai dengan viskositas < 10 cP dan bahan liquid



Komponen	Massa (kg/jam)	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO_2(_l)$	3995.4338	0.9195	0.94
$C_{18}H_{34}O_2(_l)$	211.0343	0.0486	0.89
$CO(NH_2)_2(_l)$	44.9009	0.0103	1.32
$AlCl_3(_s)$	42.2069	0.0097	2.48
$H_2O(_l)$	51.7041	0.0119	1
Total	4345.2800	1.0000	6.63

Rate massa = 5212.62 kg/jam
= 11491.73 lb/jam
ρ campuran = 57.90 lb/cuft

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

$$= \frac{11491.7336\ \text{lb/jam}}{57.8989\ \text{lb/cuft}}$$

= 198.4793 cuft/jam
= 3.3080 cuft/mnt
= 0.0551 cuft/s
= 24.7471 gpm

Asumsi aliran turbulen

Di optimum untuk aliran turbulen, Nre > 2100, digunakan persamaan :

Di_{opt} = 3.9 x $qf^{0,45}$ x $\rho^{0,13}$ **(Peters, 4 ed, pers.15 : 496)**

Dengan :

Di opt = diameter optimum ; in
qf = fluid flow rate ; cuft/s
ρ = fluid density ; lb/cuft

Di_{opt} = 3.9 x 0.2714 x 1.6949
= 1.7941 in

Dipilih pipa 3 in, sch 40 **(Mc Cabe, 5ed, App.5)**

OD = 3.5 in

ID = 3.1 in = 0.256 ft = 0.078 m

A = 1/4 x π x ID^2

= 0.051 ft²

$$\text{Kecepatan aliran} = \frac{\text{Rate Volumetrik}}{\text{Area Pipa}}$$

$$= \frac{0.0551 \text{ cuft/s}}{0.0513 \text{ ft}^2}$$

= 1.0745 ft/s

ρ reference = 62.43 lb/cuft

Sg reference = 1 lbf/lbm

μ reference = 0.00085 lb/ft.s

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

$$= \frac{57.8989}{62.43}$$

= 0.9274

Viskositas Campuran

T = 30 °C = 303.15 K

$$Log_{10}\,\mu = A + \frac{B}{T} + CT + DT^2 \qquad \mu\ Campuran = \sum_{i}^{n} \mu . Xf$$

Data Viskositas Liquid (Yaws, table 22-2)

Komponen	A	B	C	D	μ (cP)
C18H34O2(l	-6.1303	1689.3	0.008372	-6.5E-06	**1.260185177**
CO(NH2)2	-1.7534	842.39	-8.2E-13	5.47E-16	**10.60203852**
H2O	-10.2158	1792.5	0.01773	-1.3E-05	**0.815034472**
C18H35NO(	-5.475	1564.3	0.00843	-6.9E-06	**1.572672382**

Komponen	Fraksi berat	μ mix (cP)
C18H34O2(	0.0486	0.0612026
CO(NH2)2	0.0103	0.1095537
H2O	0.0097	0.0079166
C18H35NO	0.9195	1.4460537
Total	**0.988101091**	**1.6247266**

μ liq mix = 0.001091816 lb/ft.s

Perhitungan Viskositas Slurry

$$\mu_m = \mu_L[1 + 2.5\Phi + 10.05\Phi^2 + 0.00273\exp(16.6\Phi)]$$

μr = Viskositas slurry campuran (cp) **(Menon S.E, hal. 606)**

μl = Viskositas liquid (cp)

ϕ = Fraksi slurry = 1.61 % = 0.01615

% solid = 1 % % liquid = 99.03 %
ρ solid = 2.48 ρ liquic = 4.15

Sg mix = 4.12
Cv = 1.615 %

μm = 1.625 [1 + 2.5 x 0.0161 + 10.05 x 0.0003 + 0.00273
exp (16.6 x 0.0161)
= 1.70038 cp
Jadi μ mix = 0.001142652 lb/ft.s

$$N_{Re} = \frac{D \times v \times \rho}{\mu}$$

$$= \frac{0.256 \times 1.074471 \times 57.8989}{0.0011}$$

= 13920 > 2100 (Asumsi turbulen benar)

Dipilih pipa Commercial steel = 0.000046 m
ε/D = 0.00059
f = 0 **(Geankoplis,3ed,Fig.2.10-3)**
gc = 32.17 ft.lbm/s² lbf

Digunakan persamaan Bernoulli :

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

Perhitungan friksi berdasarkan **Geankoplis 3ed**, Tabel 2.10-1, hal 93

Sambungan / Fitting	Le/D
Elbow standard 90°	35
Gate valve open	9

Panjang ekuivalen suction, Le
Taksiran panjang pipa lurus = 40 ft
2 Elbow 90° = 2 x 32 x 0.256 = 16.3627 ft
1 Globe valv = 1 x 300 x 0.256 = 76.7 ft
1 Gate valve = 1 x 7 x 0.256 = 1.7897 ft

Panjang total pipa (Le) = 134.8523 ft

Friksi yang terjadi :

1 Friksi karena gesekan bahan dalam pipa

$$F_1 = \frac{2f \times v^2 \times L}{gc \times D}$$

$$= \frac{2 \times 0.007 \times 1.1545 \times 134.8523}{32.174 \times 0.256}$$

= 0.2650 ft lbf/lbm

2 Friksi karena kontraksi dari tangki ke pipa

$$F_2 = \frac{K \times v^2}{2 \times \alpha \times gc}$$

K = 0 (A tangki >>>A pipa **(Peters 4 ed ,hal. 484)**

α = 1 (untuk aliran turbulen)

$$F_2 = \frac{0.4 \times 1.1545}{2 \times 1 \times 32.2}$$

= 0.00718 ft lbf/lbm

3 Friksi karena ekspansi dari pipa ke tangki

$$F_3 = \frac{\Delta v^2}{2 \times \alpha \times gc}$$ (A1 <<< A2, maka v_1 dianggap = 0)

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

$$= \frac{1.154 - 0}{2 \times 1 \times 32.2}$$

= 0.0179 ft lbf/lbm

4 Friksi karena Elbow 90° **(Geankoplis 3[ed]. 2.10-1 hal 93)**

$$F_4 = K_f \times \frac{v_1^2}{2}$$

$$= 3 \times 0.8 \times \frac{1.154}{2}$$

= 1.2988 ft lbf/lbm

5 Friksi karena Gate Valve

$$F_5 = K_f \times \frac{v_1^2}{2}$$

$$= 0.2 \times \frac{1.1545}{2}$$

= 0.0981 ft lbf/lbm

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

= 0.265 + 0.007177 + 0.02 + 1.299 + 0.10

= 1.6870 ft lbf/lbm

P_1 = atm + Ph

= atm + ρ x g/gc x h

$= (15 \times 144) + (57.9 \times 1 \times 8.11)$
$= 2116.8 + 469.5114$
$= 2586.31 \ lbf/ft^2$
$P_2 = 1 \ atm$
$= 14.7 \ lbf/in^2$
$= 2117 \ lbf/ft^2$
$\Delta P = P_2 - P_1$
$= 2117 - 2,586.3$
$= 469.5114 \ lbf/ft^2$

$$\frac{\Delta P}{\rho} = \frac{469.5114}{57.8989} = 8.109 \ t \ lbf/lbm$$

$$\frac{\Delta v^2}{2 \times \alpha \times gc} = \frac{1.1545 - 0}{2 \times 1 \times 32}$$
$= 0.0179 \ ft \ lbf/lbm$

Asumsi : $Z_1 = 0.0000$ ft
$Z_2 = 8.1092$ ft
$\Delta Z = 8.1092$ ft
$g/gc = 1$ lbf/lbm

$$\Delta Z \frac{g}{gc} = 8.109 \times 1$$
$= 8.109$ ft lbf/lbm

Sehingga :

$$-Wf = \frac{\Delta P}{\rho} + \frac{\Delta Z \ g}{gc} + \frac{\Delta v^2}{2 \times gc \times \alpha} + \Sigma F$$
$= 8.1092 + 8.109 + 0.018 + 1.6870$
$= 17.9233$ ft lbf/lbm

$$hP = \frac{-Wf \times \text{flowrate (gpm)} \times sg}{3960}$$
$$= \frac{17.9233 \times 24.7471 \times 0.927}{3960}$$
$= 0.1039$ hP

Effisiensi pompa = 0.3 (Peters 4 ed ; fig 14-37 ; hal 520)

$$BhP = \frac{hP}{\eta \ pompa}$$
$$= \frac{0.1039}{30\%}$$
$= 0.3$ hP

Effisiensi motor = 84% (Peters 4 ed; fig 14-38 ; hal 521)

$$\text{Power motor} = \frac{\text{BhP}}{\eta\ \text{motor}}$$

$$= \frac{0.3463}{84\%}$$

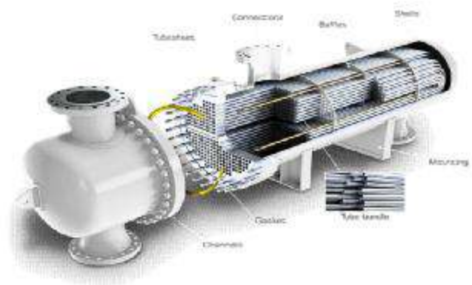
$$= 0.41 \quad \text{hP}$$

Spesifikasi:

Fungsi	=	Mengalirkan campuran oleamida dari reaktor ke mixer
Type	=	Centrifugal pump
Rate volumetril	=	24.7471 gpm
Total Dynamic	=	17.9233 ft lbf/lbm
BhP	=	0.3463 hP
Power Motor	=	0.4122 hP
Effisiensi pomp	=	30%
Effisiensi moto	=	84%
Bahan konstruk	=	Commercial steel
Jumlah	=	1 buah

20. COOLER-2 (E-212)

Fungsi : Mendinginkan campuran oleamida keluaran reaktor



bahan masuk :

Komponen	Berat (kg/jam)
$C_{18}H_{35}NO_{(l)}$	3995.4338
$C_{18}H_{34}O_2(_l)$	211.0343
$CO(NH_2)_2(_l)$	44.9009
$AlCl_3(_s)$	42.2069
$H_2O(_l)$	4345.2800
Total	8638.8559

Berat bahan masuk	=	8638.85593	kg/jam
	=	19045.3946	lb/jam
Q Serap	=	201664.777	Kkal/jam
	=	799802.504	Btu/jam
Kebutuhan air pendingin	=	13434.6855	kg/jam
	=	29618.3764	lb/jam

<u>Perhitungan ΔT LMTD</u>

Fluida dingin

Temperatur						
t1	=	30	°C	=	86	°F
t2	=	45	°C	=	113	°F

Fluida panas

Temperatur						
T1	=	160	°C	=	320	°F
T2	=	75	°C	=	167	°F

$\Delta t_1 = T_2 - t_1$
$= 320 - 113$
$= 207$ °F

$\Delta t_2 = T_1 - t_2$
$= 167 - 86$
$= 81$ °F

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

(Kern; Pers. 5.14; Hal. 89)

$$= \frac{81 - 207}{\ln \frac{81}{207}}$$

$= 134.2898$ °F

$$R = \frac{T_1 - T_2}{t_2 - t_1} = \frac{320 - 167}{113 - 86} = 6$$

$$S = \frac{t_2 - t_1}{T_1 - t_1} = \frac{113 - 86}{320 - 86} = 0.1154$$

(Kern; Pers. 5.14; Hal. 149)

F_T = 0.87 **(Kern; Fig. 18; Hal. 828)**

ΔT LMTD = ΔT LMTD x F_T

= 116.832087

Temperatur rata-rata

$t_c = t_{av}$ air pendingin

$$= \frac{86 + 113}{2}$$

= 99.5 °F

$T_c = T_{av}$ gas

$$= \frac{320 + 167}{2}$$

= 243.5 °F

Trial Ukuran Cooler (Kern. Pg :229)

a. Trial Ud = 250 Btu/hr.ft². °F **(Kern T.8, Pg : 840)**

$$A = \frac{Q}{UD \times \Delta T\ LMTD}$$ **(Kern; Pers. 7.6; Hal. 140)**

$$= \frac{799802.5042}{250 \times 116.8321}$$

= 27.3829741 ft²

Berdasarkan Kern tabel 9 & 10 maka dipilih :

Tube Side

OD	=	1	in
BWG	=	18	
Wall thickness	=	0.049	in
ID	=	0.902	in
Passes	=	2	
a't	=	0.639	in²
a"	=	0.2618	ft²/ft.panjang
Pitch	=	1 1/4	in
Panjang tube	=	4	ft

Shell Side

Passes	=	1	
ID	=	21 1/4	in

$$N_t = \frac{A}{L \times a''}$$

$$= \frac{27.38297415}{4 \times 0.2618}$$

$$= 26.1488$$

Nt distandarkan dan IDs didapatkan dari **tabel 9 Kern**
Diketahui Nt 354,69; 2 passes; 3/4in.OD on 1-in square pitch
Maka diperoleh : Nt standar = 398
ID shell = 21 1/4

A baru = Nt standar x Panjang tube x a"
= 398 x 4 x 0.2618
= 416.7856 ft²

$$UD\ baru = \frac{Q}{Abaru \times \Delta T\ LMTD}$$

$$= \frac{799802.5042}{416.7856 \times 116.832087}$$

= 16.4251 Btu/hr.ft². °F

$$\text{Baffle spacing} = \frac{\text{ID Shell}}{5}$$ **(Kern pers 11.4; Pg.226)**

= 4.25 in

Fluida Dingin (Tube Side)	Fluida Panas (Shell Side)
Air	**Gas NH_3 dan CO_2**
1) Flow area (at)	**1) Flow area**
at = $= \frac{Nt \times a't}{144 \times n}$	C" = Pt - OD
$= \frac{398 \times 0.639}{144 \times 2}$	= 1 - 1
= 0.8831 ft²	= 1/4 in
	B = 4 1/4 in
	as = ID x C" x B / 144 Pr
	$= \frac{21 \times 1/4 \times 4.3}{144 \times 1\ 1/4}$
	= 0.1254 ft²
2) Mass Velocity (Gt)	**2) Mass Velocity (Gs)**
$Gt = \frac{w}{at}$	$Gs = \frac{w}{as}$
$= \frac{29618.3764}{0.8831}$	$= \frac{19045.3946}{0.1254}$
= 33540.5211 lb/jam.ft2	= 151835.948 lb/jam.ft2

3) Pada tc = 99.5 °F

μ = 0.75 cps **(fig.15)**
= 1.815 lbm/jam.ft

$Di = \frac{0.9}{12}$
= 0.0752 ft

$Ret = \frac{D \times Gt}{\mu}$
$= \frac{0.0752 \times 33541}{1.8150}$
= 1389.052

4) jH = 78 (fig.24)

5) Pada tc = 99.5 °F

k = 0.362 Btu/hr.ft²(°F/ft)
(Kern T.5, Pg:800)

Cp = 0.98 Btu/lb.°F
(Kern, F.2, Pg:804)

$\left(\frac{Cp.\mu}{k}\right)^{1/3} = 1.7001$

6) $\frac{hi}{Øt} = jH \times \frac{k}{D} \times \left(\frac{Cp \times \mu}{k}\right)^{1/3}$
$= 78 \times \frac{0.362}{0.0752} \times 1.7001$
= 638.6201

7) $\frac{hio}{Øt} = \frac{hi}{Øs} \times \frac{ID}{OD}$
$= 638.6201 \times \frac{21\ 1/4}{1}$
= 13570.68

8) $tw = tc + \frac{hi/Øt \times (Tc - tc)}{hio/Øs + hi/Øt}$
$= 100 + \frac{13571 \times 144}{361.43 + 13571}$
= 239.7643 °F

μw = 0.2 Cp
= 0.484 lb/ft.hr

3) Pada Tc = 243.5 °F

μ = 0.0532 cps **(fig.15)**
= 0.1287 lbm/jam.ft

$De = \frac{0.95}{12}$ **(fig.28)**
= 0.0792 ft

$Res = \frac{D \times Gs}{\mu}$
$= \frac{0.0792 \times 151836}{0.1287}$
= 93366.26

4) jH = 430 (fig.28)

5) Pada Tc = 243.5 °F

k = 0.0533 Btu/hr.ft²(°F/ft)
(Kern T.5, Pg:801)

Cp = 0.805 Btu/lb.°F
(Kern, F.3, Pg:805)

$\left(\frac{Cp.\mu}{k}\right)^{1/3} = 1.248$

6) $\frac{hi}{Øs} = j_H \times \frac{k}{D} \times \left(\frac{Cp \times \mu}{k}\right)$
$= 430 \times \frac{0.0533}{0.079} \times 1.2$
= 361.4325

7) $tw = Tc + \frac{hi/Øs \times (Tc - tc)}{hio/Øt + ho/Øs}$
$= 244 + \frac{361.43 \times 144}{13571 + 361.43}$
= 247.24 °F

8) μw = 0.060 cP
= 0.145 lb/ft.hr

$Øt = \left(\frac{\mu}{\mu w}\right)^{0,14}$

$= \left(\frac{0.1287}{0.145}\right)^{0.14}$
= 0.9833

$$Øs = \left(\frac{\mu}{\mu w}\right)^{0,14}$$

$$= \left(\frac{1.815}{0.484}\right)^{0.14}$$

$$= 1.2033$$

9) Faktor koreksi hio

$$hio = \frac{hio/Øt}{Øt}$$

$$= 16329.24$$

12. Clean overall coefficient, Uc :

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

$$= \frac{361.43 \times 16329}{361.43 + 16329}$$

$$= 353.6057 \text{ Btu/hr ft}^2 \text{ °F}$$

13. Dirt factor, Rd :

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

$$= \frac{353.61 - 16.4251}{353.61 \times 16.4251}$$

$$= 0.058$$

Rd perhitungan > Rd data **(Kern T 12 Hal 845)**

0.058 >= 0.002 untuk media air

(memenuhi, karena Rd hitung > Rd allowable)

Fluida Dingin (Tube Side)	Fluida Panas (Shell Side)
Air	**Gas NH3 dan CO2**
Pressure Drop	
a. Untuk Ret : 1389.05189	**a'. Untuk Res :** 93366.261
f = 0.00025 ft^2/in^2	f = 0.0015 ft^2/in^2
(Kern, fig 26 hal 836)	**(Kern, fig 29 hal 839)**
specific volume of steam :	
(Kern,T 7 Hal 816)	s = 0.59
v = 6.655 ft^3/lb	
$s = \frac{0.1503}{62.5}$	
= 0.0024	
b. $\Delta Pt = \frac{1}{2} \times \frac{f \times Gt^2 \times L \times n}{5,22 \times 10^{10} D. s.\varphi t}$	**b'.** No of crosses
= 0.1192537	$N + 1 = \frac{12 L}{B}$
$\Delta Pt < 10$ psi	= 11.29412
(Memenuhi untuk air)	

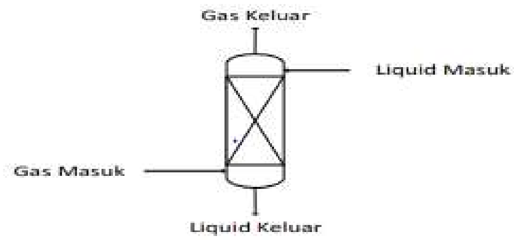
	c'. ΔPs $= \dfrac{f \times Gs^2 \times De \times (N + 1)}{5{,}22 \times 10^{10} \times De \times s \times \varphi s}$ = 0.013 psi ΔPs < 2 psi (Memenuhi untuk gas)

Spesifikasi :

Fungsi	=	Mendinginkan keluaran reaktor	
Type	=	Shell and tube, 1-2 exchanger	
Tube			
Inside Diameter	=	1	in
Outside Diameter	=	1	in
Panjang	=	4	ft
Pitch	=	1.25	in
Jumlah Tube	=	398	buah
Passes	=	2	
BWG	=	18	BWG
Shell			
Inside Diameter	=	21.25	in
Passes	=	1	

21. ABSORBER (D-220)

Fungsi : Menyerap gas NH_3 dan CO_2 hasil keluaran reaktor dengan air
Tipe : Packed Column



Kondisi Operasi : Tekanan = 1 atm = 1.0133 bar
Suhu = 30 C = 303.5 K

A. Komposisi bahan masuk :

Komponen	BM	Massa	Kmol/jam	Yi	Yi x BM
$NH_{3\ (g)}$	17	241.7166	14.2186	0.5	8.5
$CO_{2\ (g)}$	44	625.6195	14.2186	0.5	22
Total		867.3362	28.4373	1	30.5

Komponen	Yi	Tc (K)	Pc (bar)	ω
$NH_{3\ (g)}$	0.5	405.5	112.8	0.253
$CO_{2\ (g)}$	0.5	304.2	73.8	0.225
Total	1			

Komponen	Tc.Yi	Pc.Yi	ω.Yi
$NH_{3\ (g)}$	202.75	56.4	0.1265
$CO_{2\ (g)}$	152.1	36.9	0.1125
Total	354.85	93.3	0.239

Tr = 0.855291
Pr = 0.01086
ω = 0.239

Dari smit vannes Appendix E table E1 dan E2 diperoleh harga
z0 = 0.834
z1 = 0.238
z = 0.891
R = 0.08206 m³·atm/(kmol·K)

$$\rho \text{ campuran} = \frac{P \times BM}{z \times R \times T}$$

$$= \frac{1.0133 \times 30.5}{0.891 \times 0.0821 \times 303.5}$$

$$= 1.392855 \text{ kg/m}^3$$

$$\text{Rate Volumetrik} = \frac{\text{Rate Massa}}{\rho \text{ campuran}}$$

$$= \frac{867.3362}{1.392855}$$

$= 622.7036248$ m³/jam

$= 622703.6248$ L/jam

Efisiensi Absorber 99% (Ludwig, 1999)

Maka bahan yang lolos

NH3 yang terserap	=	2716.04689
NH3 yang lolos	=	27.4348171
CO2 yang terserap	=	3509.48983
CO2 yang lolos	=	35.4493922

B. Komposisi Gas Keluar

Suhu = 30 C = 303.5 K

Komponen	BM	Massa	Kmol/jam	Yi	Yi x BM
$NH_{3\,(g)}$	17	27.43481706	1.61381277	0.667008	11.33913
$CO_{2\,(g)}$	44	35.44939222	0.805668	0.332992	14.65165
Total		62.88420928	2.41948077	1	25.99079

Komponen	Yi	Tc (K)	Pc (bar)	ω
$NH_{3\,(g)}$	0.667008	405.5	112.8	0.253
$CO_{2\,(g)}$	0.332992	304.2	73.8	0.225
Total	1			

Komponen	Tc.Yi	Pc.Yi	ω.Yi
$NH_{3\,(g)}$	270.4717	75.23849	0.168753
$CO_{2\,(g)}$	101.2962	24.57482	0.074923
Total	371.7679	99.81331	0.243676

Tr = 0.81637

Pr = 3.040677

ω = 0.243676

Dari smit vannes Appendix E table E1 dan E2 diperoleh harga

z0 = 0.24

z1 = 0.025

z = 0.246

R = 0.08206 m³·atm/(kmol·K)

$$\rho \text{ campuran} = \frac{P \times BM}{z \times R \times T}$$

$$= \frac{1.0133 \times 25.9907869}{0.246 \times 0.0821 \times 303.5}$$

$= 4.296833$ kg/m³

$$\text{Rate Volumetrik} = \frac{\text{Rate Massa}}{\rho \text{ campuran}}$$
$$= \frac{62.88421}{4.296833}$$
$$= 14.63501258 \text{ m}^3/\text{jam}$$
$$= 14635.01258 \text{ L/jam}$$

C. Komposisi liquid masuk

Bahan masuk = 5024.402299 kg/jam = 11076.8978 lb/jam
ρ bahan = 62.2407 lb/cuft
sg bahan = 63.2407
μ bahan = 0.84 cps

$$\text{Rate Volumetrik} = \frac{\text{Rate Massa}}{\rho \text{ campuran}}$$
$$= \frac{11076.9 \text{ lb/jam}}{62.2407 \text{ lb/cuft}}$$
$$= 177.9687214 \text{ cuft/jam}$$

D. Komposisi Liquid Keluar

Komponen	Massa	fraksi	ρ (g/cc)	ρ (lb/cuft)	kmol/jam
$NH_{3\,(aq)}$	2716.046889	0.241428	0.769	48.00867	159.486018
$CO_{2\,(aq)}$	3509.48983	0.311956	0.001977	0.123424	79.7430091
$H_2O_{\,(aq)}$	5024.402299	0.446616	0.99	61.8057	278.823657
Total	11249.93902	1			518.052684

$$\rho \text{ campuran} = \frac{1}{\dfrac{\text{fraksi berat}}{\rho \text{ komponen}}}$$

$$\rho \text{ campuran} = \frac{1}{\dfrac{0.241428}{48.00867} + \dfrac{0.311956}{0.123424} + \dfrac{0.446616}{61.8057}}$$
$$= 0.393736379 \text{ lb/cuft}$$

$$\text{Rate Volumetrik} = \frac{\text{Rate Massa}}{\rho \text{ campuran}}$$
$$= \frac{24801.84 \text{ lb/jam}}{0.393736 \text{ lb/cuft}}$$
$$= 62990.98039 \text{ cuft/jam}$$

E. Diamater Absorber

V = flow rate gas masuk = 0.00789924
L = flow rate liquida masuk = 0.07753707
Mg = berat molekul gas = 30.5
M_l = berat molekul liquid = 18
ρ_G = densitas gas masuk = 1.39285549

ρ_L = densitas liquid masuk = 996.971533
μ_l = viscositas liquid = 0.00084 Pa s

$$\frac{L \times Ml}{V \times Mg}\left(\frac{\rho G}{\rho L - \rho G}\right)^{1/2} = 0.21667669$$

Pressure drop yang diijinkan untuk absorber 200-400 Pa/m
diambil 200 Pa/m

$$\frac{Gf^2 \times Cf \times \mu l^{0.1}}{\rho G \times (\rho L - \rho G)} = 0.049$$ (fig. 4-32 Ulrich hal.198)

Cf = 100 = packing constan
G^2 = 1044.594
G = 32.32018

$$D = \left(\frac{4V \times M_g}{3{,}14 \times G}\right)^{1/2}$$

D = 0.4872 m
= 1.6 ft

F. Menentukan Jumlah Stage

Dengan metode Mc Thiele

1. Membuat kurva kestimbangan

Data konstanta antoine (Yaws, 1999)

Komponen	A	B	C	D	E
NH_3	37.158	-2.028.E+03	-1.160.E+01	7.4625.E-03	-9.5811E-12
CO_2	35.017	-1511.9	-11.334	9.3368E-03	1.7136.E-09

Log P^{sat} = A+B/T+C log T + D.T+ E.T^2

Tekanan = 1 atm = 760 mmHg = 101.33 kPa
Suhu = 30 C = 303.5 K

Hukum Raoult
yi. P = xi. Pi ^{sat}

keterangan : yi = L - phase mole fraction
xi = V - phase mole fraction
Pi ^{sat} = Vapor pressure of pure species i
P = Total pressure

ln P^{sat} = 3.946 kPa
P^{sat} = 51.717 = 0.5104 atm
P* = 0.228
P*/Pt = 0.447
p/pt = 0.392
y* = 0.392
Y* = 0.295

X_1	Y_1
0.00	0.0000
0.10	0.0392
0.20	0.0784
0.30	0.1176
0.40	0.1567
0.50	0.1959
0.60	0.2351
0.70	0.2743
0.80	0.3135
0.90	0.3527
1.00	0.3918

2. Neraca Massa Overall dan Komponen

Neraca Massa

$L_o + V_{N+1} = L_N + V_1$

Pelarut liquid (absorben)

L_o = 279.13 kmol/jam
X_o = 0.00
L_N = 518.4 kmol/jam
X_N = 0.0983

Neraca Massa Komponen

$L_o\, x_o + V_{N+1}\, y_{N+1} = L_N\, x_N + V_1\, y_1$

Vapor/gas

V_{N+1} = 28.44 kmol/jam
Y_{N+1} = 0.3800
V_1 = 2.42 kmol/jam
Y_1 = 0.22

3. Pelarut

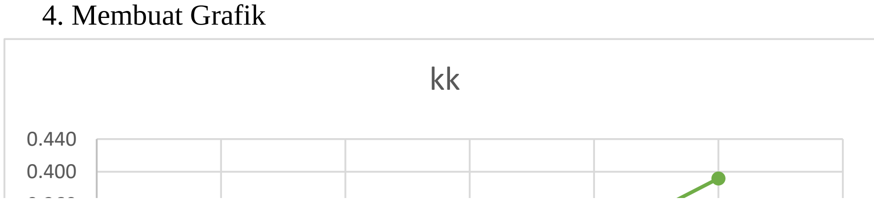
$$\frac{Lmin}{V} = \frac{Y_{N+1} - Y_1}{X_{nmax} - X_o}$$

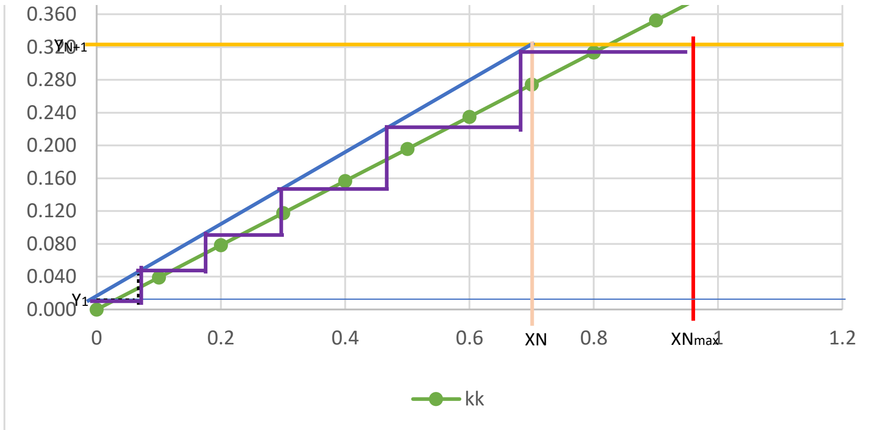
$$= \frac{0.3800 - 0.217}{0.980 - 0.00}$$

= 0.167

L/V op = 0.250

4. Membuat Grafik





5. Stage Ideal dan Aktual

Didapatkan stage ideal = 5
Efisiensi stage = 80% **(Ulrich, Tabel. 4-18, pp. 188)**
Stage aktual = 7

G. Tinggi Tower

Ulrich pers. 4-84/88, didapat Height Equipment to Theoretical Plate, HETP =

HETP = $D^{0,3}$
= 0.4973 m

Tinggi tower = HETP x N
Tinggi tower = 0.4973 x 7
Tinggi tower = 3.4812 m
= 11.421 ft
= 137.06 in

H. Tebal Shel dan Tebal Tutup

1. Menghitung Tebal Shell

P operasi = 1.00 atm = 14.70 psi
Asumsi P design dilebihkan 10% untuk faktor keamanan
P design = 1.1 x 14.70 psi
= 16.166 psi

Tebal shell berdasarkan ASME code untuk bejana silinder:

$$t_{min} = \frac{P \times ri}{f E - 0.6 P} + C$$ **(Brownell, Pers. 13-1, pp. 254)**

Keterangan :
tmin = Tebal shell minimum (in)
P = Tekanan design (psi)
ri = Jari-jari tangki (in)
f = Allowable stress, dilihat dari bahan kontruksi
= 12,650 psi *untuk bahan carbon steel SA-283 grade C*
(Brownell, Table 13-1, pp. 251)
E = Faktor pengelasan
= 0.8 *untuk jenis double welded butt joint*
(Brownell, Table 13-2, pp. 254)

C = Faktor korosi (in) : 1/16 - = $\frac{1}{8}$ in

ri = $\frac{1}{2}$ x 19.18 in = 9.591 in

Asumsi = 5/16

tmin = $\frac{P \times ri}{f\,E - 0.6\,P}$ + C

1/3 = $\frac{16.1655 \times 9.5913}{f \times 0.8 - 0.6 \times 16.166} + \frac{1}{8}$

f = 1,045.78 in

Karena f hitung < f allowable (12.650) maka tebal shell 5/16 in dapat digunakan

2. Menghitung Tebal Tutup Atas dan Bawah

Tutup atas berbentuk torispherical dished head

Diameter luas shell (OD)

OD = ID + 2 ts

= 19.18 + 2 x 1/3

= 19.80758 in

= 1.6506 ft

icr = 3/4 in **(Brownell, T-5.7, Hal. 89)**

rc = 9 in

<u>Tebal tutup atas</u>

Karena icr > 6% rc, maka digunakan persamaan 7.76 dan 7.77

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

(Brownell, Hal. 138)

$$W = \frac{1}{4}\left(3 + \left(\frac{r_c}{r_1}\right)^{1/2}\right)$$

Keterangan :

t_h = Tebal tutup (head) shell min ; in

r_c = *Radius of curfative* sama dengan diameter ; in

W = Faktor stress intensif untuk torisph

P = Tekanan tangki ; psi

C = Faktor pengelasan = 1/8 in

e = Faktor pengelasan, digunakan *double welded* = 0.8

f = *Stress allowable* , bahan konstruksi *carbon steel* tipe SA-283 grade C, maka f = 12650 lb/in²

(Brownell; T.13-1, Hal. 251)

$$W = \frac{1}{4}\left(3 + \left(\frac{r_c}{r_1}\right)^{1/2}\right)$$

$$= \frac{1}{4}\left(3 + \sqrt{\frac{9}{0.75}}\right)$$

= 1.616025

Asumsi tebal head = 3/16 in

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

$$1/5 = \frac{16.1655 \times 9 \times 1.616025}{2 \times f \times 0.8 - 0.2 \times 16.166} + 1/8$$

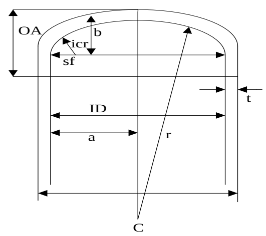
$$0.06 = \frac{235.1153629}{1.6\ f - 3.233109}$$

$$0.1\ f - 3.233109 = 235.115363$$

$$0.1\ f = 238.3485$$

$$f = 2383.485\ \text{lb/in}^2$$

f hitung lebih kecil dari f all, jadi tebal head = 3/16 in dapat digunakan



Menentukan panjang head :

ID = 19.18 in

OD = 19.8076 in

Berdasarkan penentuan dimensi dished head halaman 87 B&Y diperoleh angka :

$$a = \frac{ID}{2} = \frac{19.18258}{2} = 9.591291\ \text{in}$$

$$BC = rc - icr = 9 - 0.75 = 8.25\ \text{in}$$

$$AB = \frac{ID}{2} - icr = \frac{19.18}{2} - 0.75 = 8.841291\ \text{in}$$

$$AC = (BC^2 - AB^2)^{0.5} = -5.05\ \text{in}$$

$$b = rc - AC = 14.05\ \text{in}$$

Dari tabel 5.8 hal. 93 (Brownell & Young) untuk tebal head 5/16 in nilai sf :

sf = 1.5 - 3 in

dipilih sf = 2 in

$$OA = th + b + sf$$
$$= 3/16 + 14.05 + 2$$
$$= 16.24\ \text{in}$$
$$= 1.353372121\ \text{ft}$$
$$= 0.412507822\ \text{m}$$

Total Tinggi Tangki

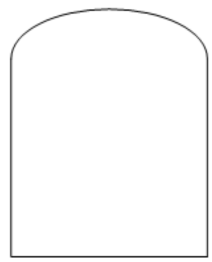
H total	=	(	2	x	H tutup	)	+	H silinder
	=	(	2	x	16.2	)	+	137.055
	=	169.5361	in					
	=	4.3062	m					
	=	14.1280	ft					

Spesifikasi Absorber

Fungsi	=	Menyerap gas NH_3 dan CO_2 hasil keluaran reaktor dengan air				
Tipe	=	Packed Column				
Jenis Packing	=	Rasching Ring ceramic				
Jumlah stage	=	7				
Diameter shell	=	1.6	ft	=	0.487238	m
Tinggi shell	=	14.1280	ft	=	4.306218	m
Tinggi tutup	=	1.353372	ft	=	0.412508	m
Tebal shell	=	5/16	in			
Tebal tutup	=	3/16	in			

22. TANGKI PENAMPUNG-1 (F-221)

Fungsi	=	Menampung liquid dari absorber
Type	=	Silinder tegak, tutup bawah datar dan tutup atas torispherical
Dasar Pemillihan	=	Umum digunakan untuk liquid pada tekanan atmosfer
Kondisi Operasi	=	Tekanan operasi = 1 atm
		Suhu operasi = 30 °C
		Waktu tinggal = 3 hari



Komponen bahan masuk :

Komponen	Berat (kg/jam)	Fraksi Berat	ρ (gr/ml)
$CO_2(_{aq})$	619.3633	0.0014	0.771
$NH_3(_{aq})$	239.2995	0.0006	1.977
$H_2O(_{l})$	432321.9435	0.9980	1
Total	**433180.6063**	**1**	

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62.43 \text{ lb/cuft}$$

$$= \frac{1}{\frac{0.00}{0.77} + \frac{6E\text{-}04}{1.977} + \frac{0.998}{1}} \times 62.43 \text{ lb/cuft}$$

$$= 62.4205 \text{ lb/cuft}$$

Rate Massa = 433180.6063 kg/jam
= 3253.2891 lb/jam

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

$$= \frac{3253.2891 \text{ lb/jam}}{62.42 \text{ lb/cuft}}$$

$$= 52.1189 \text{ cuft/jam}$$

Direncanakan penyimpanan untuk 7 hari, 2 buah tangki
sehingga volume bahan :

Volume bahan = Rate volumetrik x waktu tinggal

$$= \frac{52.1189 \times 24 \times 7}{2}$$

= 4377.9870 cuft

Asumsi bahan mengisi 80% volume tangki, maka :

$$\text{Volume tangki} = \frac{\text{Volume bahan}}{80\%}$$

$$= \frac{4377.9870}{80\%}$$

= 5472.4838 cuft

Menentukan dimensi tangki

Asumsi dimensi ratio H/D = 2 **(Ulrich T.4-27)**

H = 2 D

$$\text{Volume silinder} = \frac{\pi}{4} \times D^2 \times H$$

$= 0.785 \times D^2 \times 2\ D$

$= 1.57\ D^3$

Tutup atas menggunakan torispherical dished, sehingga :

V tutup atas = $0.000049\ D^3$ (Brownell; pers. 5.11, hal. 88)

jika diambil α = 30 °

Volume tangki = V silinder + V tutup atas

$5472.4838 = 1.57\ D^3 + 0.000049\ D^3$

$5472.4838 = 1.5700\ D^3$

D^3 =	3485.5497		H =	2 D	
D =	15.1620	ft	=	30.3240	ft
=	184.5961	in	=	369.1922	in
=	4.6214	m	=	9.2428	m

Menentukan tinggi liquid dalam shell

$$\text{Volume liquid} = \frac{\pi}{4} \times D^2 \times H$$

$4{,}377.9870 = 0.785 \times 229.8869 \times H$

$4{,}377.9870 = 180.4612\ H$

H liq = 24.2600 ft

Menentukan Tekanan Design

P operasi = 1 atm = 14.7 psi

P hidrostatis = ρ x g/gc x H_L

$$= 62.4205 \ \frac{\text{lbm}}{\text{cuft}} \times 1 \ \frac{\text{lbf}}{\text{lbm}} \times 24.2600 \ \text{ft}$$

$$= 1514.321528 \ \frac{\text{lbf}}{\text{ft}^2}$$

= 10.5161 psi

P design = P operasi + P hidrostatis
= 14.7 + 10.5161
= 25.2161 psi

Untuk faktor keamanan, P design dipilih 10% lebih besar

P design = 1.1 x 25.2161
= 27.7377 psi

Menentukan Ketebalan Dinding Tangki

Tipe material penyusun tangki adalah Stainles Steel. Hal ini disebabkan :

- Mempunyai allowable stress yang besar
- Harga yang relatif lebih murah

Penentuan tebal shell :

$$t_{min} = \frac{P \ \text{X} \ ri}{f \ E - 0.6 \ P} + C$$

Dimana :

t_{min} = tebal shell minimum (in)
P = tekanan tangki (psi)
ri = jari-jari tangki (in; 1/2D) =
C = faktor korosi (in: 1/8D) **(Brownell, pg 254)**
E = faktor pengelasan (double welded; 0.8)
f = Stress allowable, bahan konstruksi *carbon steel SA-167 Grade 3*
Tipe 304, maka f all = 16,650 lb/in² **(Perry 7ed; T.28-11)**

Asumsi tebal shell = 3/8 in

$$t_{min} = \frac{P \times ri}{f \ E - 0.6 \ P} + C$$

$$3/8 = \frac{27.7377339 \times 92.2981}{f \times 0.8 - 0.6 \times 27.74} + 1/8$$

$$1/4 = \frac{2560.1389}{0.8 \ f - 16.6426}$$

0.2 f - 4.1607 = 2560.1389

0.20 f = 2564.2996

f = 12821.4980 psi

f hitung lebih kecil dari f *allowable* , jadi tebal shell 3/8 memenuhi

Menentukan Tebal Tutup Atas dan Bawah

Tutup atas dan bawah dipilih torispherical

OD = ID + 2 ts

= 184.596 + 2 (3/8)

= 185 in

Berdasarkan **Tabel 5.7 Brownell** didapatkan :

ts = 3/8

icr = 11 1/2 in

rc = 170 in

$$\frac{icr}{rc} = 6.8\%$$

karena icr > 6% rc, maka digunakan persamaan 7.76 dan 7.77

Tebal Standart Toripherical Dished (atas)

$$th = \frac{P \times rc \times W}{2\ f\ E - 0{,}2\ P} + C$$

Dimana:

th = tebal head (in)

W = faktor intensifikasi stress

f = Stress allowable, bahan konstruksi *carbon steel SA-167 Grade 3*
Tipe 304, maka f all = 16,650 lb/in² **(Perry 7ed; T.28-11)**

C = faktor korosi (in) = 1/8 , 10 tahun
(Tabel 6. Timmerhaus, hal.542)

E = faktor pengelasan digunakan double welded E = 0.8
(Tabel 5-7, Brownell, hal.254)

P = tekanan desain

Faktor Intensifikasi stress (W)

$$W = \frac{1}{4} \times \left(3 + \sqrt{\frac{rc}{icr}}\right)$$

$$= \frac{1}{4} \times 3 + \sqrt{\frac{170}{13}}$$

= 1.7112 in

Sehingga tebal tutup atas :

Asumsi tebal head = 4/9

$$th = \frac{P \times rc \times W}{2\ f\ E - 0{,}2\ P} + C$$

$$7/16 = \frac{27.7377 \times 170 \times 1.7112}{2 \times f \times 0.8 - 0.2 \times 27.73773} + 1/8$$

$$0.31 = \frac{8069.0364}{1.6\ f - 5.5475}$$

$$0.5\ f - 2 = 8069.0364$$

$$f = 16141.540$$

f hitung lebih kecil dari f *allowable* , jadi tebal tutup atas 7/16 memenuhi

Digunakan tebal head standart = 7/16 in

Tebal botton = tebal head = 7/16 in

untuk th = 7/16 in, maka sf = 1,5 - 3,5

(Tabel 5.6. Brownell, hal.88)

Diambil sf = 2

Menghitung tinggi tutup atas (OA)

BC = rc - icr
= 170 - 11.5
= 159 in

$$AB = \frac{1}{2} Di - icr$$

$$= \frac{1}{2} \times 184.596 - 11.5$$

= 80.7981 in

$$b = rc - (BC^2 - AB^2)^{0,5}$$

$$= 170 - (25122 - 6528)^{0,5}$$

= 33.6 in

Jadi, tinggi tutup adalah

OA = b + sf + t
= 33.6 + 2 + 7/16
= 36.0780 in
= 3.0065 ft

untuk tebal tutup bawah datar karena tutup menumpang diatas semen, maka

tebal tutup = 1/4 in (Brownell & Young; 58)

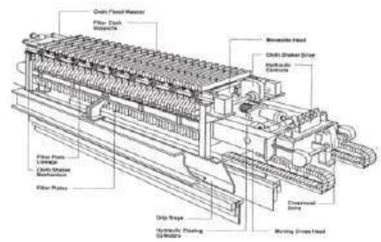
Spesifikasi :

Fungsi	=	Menampung liquid dari absorber
Type	=	Tangki berbentuk silinder tegak dengan tutup atas berbentuk Torispherical Head dan tutup bawah plate datar
Volume	=	5472.4838 cuft
Diameter shell	=	15.1620 ft

Tinggi shell	=	30.32404	ft
Tinggi tutup atas	=	3.01	ft
Tebal shell	=	3/8	in
Tebal tutup atas	=	7/16	in
Tebal tutup bawah	=	1/4	in
Bahan konstruksi	=	*Carbon steel SA-167 Grade 3*	
Jumlah	=	1 buah	

25. FILTER PRESS (H-320)

Fungsi : Memisahkan padatan sisa reaksi dari campuran oleamida
Type : Plate & Frame Filter Press
Dasar pemilihan : Efektif dan sesuai dengan jenis bahan



Feed masuk dari mixer

Komponen	Massa (kg/jam)	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO_{(l)}$	3995.4338	0.9195	0.94
$C_{18}H_{34}O_{2(l)}$	211.0343	0.0486	0.895
$CO(NH_2)_{2(s)}$	44.9009	0.0103	1.32
$AlCl_{3(s)}$	42.2069	0.0097	2.48
$H_2O_{(l)}$	51.7041	0.0119	1
Total	**4345.280011**	**1**	**6.635**

Waktu pembersihan = waktu pembongkaran + pengambilan cake + pencucian cake + pencucian cake and frame + pemasangan ulang
= (15 + 15 + 15 + 15) menit
= 60 menit = 1 jam

Waktu siklus operasi = 2 jam (terdiri dari 1 jam bongkar pasang dan 1 jam operasi)

Komposisi Filtrat Keluar

Komponen	Massa (kg/jam)	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO_{(l)}$	3955.4795	0.9381	0.94
$C_{18}H_{34}O_{2(l)}$	208.9240	0.0495	0.895
$CO(NH_2)_{2(s)}$	0.4490	0.0001	1.32
$AlCl_{3(s)}$	0.4221	0.0001	2.48
$H_2O_{(l)}$	51.1871	0.0121	1
Total	**4216.4616**	**1**	**6.635**

$$\rho \text{ filtrat} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62.43 \quad \text{lb/cuft}$$

$$= \frac{1}{\frac{0.9381}{0.9400} + \frac{0.0495}{0.895} + \frac{0.0001}{1.3200} + \frac{0.0001}{2.48} + \frac{0.0121}{1}} \times 62.43 \text{ lb/cuft}$$

$= 58.5864$ lb/cuft

Rate Massa Filtrat = 4216.4616 kg/jam
= 9295.6112 lb/jam

$$\text{Rate volumetrik} = \frac{\text{Rate Massa}}{\text{Densitas}}$$

$$= \frac{9295.6112 \text{ lb/jam}}{58.5864 \text{ lb/cuft}}$$

$= 158.6651$ cuft/jam

Volume Filtrat = 158.6651 cuft/jam x 1 jam
= 158.6651 cuft/jam
= 1186.898 gal
= 4.492894 m^3

Komposisi Cake Keluar

Komponen	Massa (kg/jam)	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO_{(l)}$	39.9543	0.3102	0.94
$C_{18}H_{34}O_{2(l)}$	2.1103	0.0164	0.895
$CO(NH_2)_{2(s)}$	44.4519	0.3451	1.32
$AlCl_{3(s)}$	41.7848	0.3244	2.48
$H_2O_{(l)}$	0.5170	0.0040	1
Subtotal	128.8184347	1	6.635

$$\rho \text{ campuran cake} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62.43$$

$$= \frac{1}{\frac{0.3102}{0.9400} + \frac{0.0164}{0.895} + \frac{0.3451}{1.3200} + \frac{0.3244}{2.48}}$$

$$\frac{}{+\ \frac{0.0040}{1}} \times 62.43$$

= 83.8561 lb/cuft
= 1343.2491 kg/m^3

Rate Massa Cake = 128.8184 kg/jam
= 283.9931 lb/jam

Rate volumetrik = $\frac{\text{Rate Massa}}{\text{Densitas}}$
= $\frac{283.9931 \text{ lb/jam}}{83.8561 \text{ lb/cuft}}$
= 3.3867 cuft/jam

Volume Cake = 3.3867 cuft/jam x 1 jam
= 3.386672 cuft/jam
= 25.33407 gal
= 0.0959 m^3

Rata-rata rate filtrasi untuk larutan dengan viskositas tinggi 1 - 2 gal/ft^{2}jam
Dipilih = 2 gal/ft^{2}jam **(Perry, 5^{ed} T.19-18)**

Luas frame total = $\frac{\text{Volume filtrat}}{\text{Rate filtrasi}}$
= $\frac{1186.898}{2}$
= 593.449 ft^2

Dalam design ini dipilih ukuran plate and frame 35 x 35 in
dan jenis metal dari T.19 - 17 Perry 5ed, diperoleh
Luas efektif = 20 ft^2
Total kapasitas = 0.650 cuft
Jumlah frame (N) = $\frac{\text{Luas frame}}{\text{Luasefektif}}$
= $\frac{593.449}{20}$
= 29.7 ≈ 51 buah
Plate and frame yang dipakai = (2 x N) - 1
= (2 x 51) - 1
= 101 buah

Jumlah plate = 101 - 51
= 50 buah

Diketahui range tebal frame = 0,25 in - 8 in (**Mc Cabe 3^ed; hal 1004**)

Volume cake tiap frame $= \dfrac{\text{Volume cake}}{\text{Jumlah frame}}$

$= \dfrac{3.3867}{51}$

= 0.06641 cuft

Tebal frame $= \dfrac{\text{Volume cake tiap frame}}{\text{Luas efektif}}$

$= \dfrac{0.06641}{20}$

= 0.0033 ft
= 0.039843 in

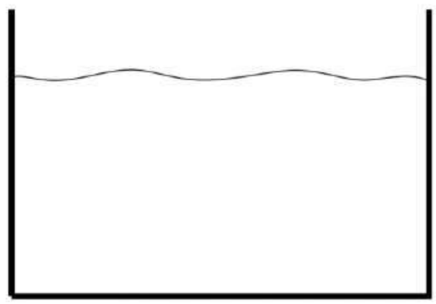
Diambil tebal frame : 1 in
Panjang total plate and frame filter press = 101 x 1
= 99 in
= 8 ft

Spesifikasi :

Fungsi	:	Memisahkan padatan sisa reaksi dari campuran oleamida
Type	:	Plate and Frame Filter Press
Jumlah plate & frame	:	101 buah
Panjang filter press	:	8.25 in
Ukuran filter press	:	35 x 35 in
Tebal tiap frame	:	1 in
Cycle operasi	:	2 jam
Jenis filter	:	metal
Jumlah	:	2 buah

24 BAK PENAMPUNG (F-321)

Fungsi : Menampung keluaran cake dari filter press



Komposisi bahan masuk:

Komposisi	Massa (kg/jam)	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO_{(l)}$	39.9543	0.31016	0.94
$C_{18}H_{34}O_{2(l)}$	2.1103	0.01638	0.895
$CO(NH_2)_{2(s)}$	44.4519	0.34507	1.32
$AlCl_{3(s)}$	41.7848	0.32437	2.48
$H_2O_{(l)}$	0.5170	0.00401	1
Total	**128.8184**	**1**	

Perhitungan:

$$\rho \text{ filtrat} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62.43 \text{ lb/cuft}$$

$$= \frac{1}{\frac{0.3102}{0.9400} + \frac{0.0164}{0.895} + \frac{0.3451}{1.3200} + \frac{0.3244}{2.48} + \frac{0.0040}{1}} \times 62.43 \text{ lb/cuft}$$

$$= 83.8561 \text{ lb/cuft}$$

Rate Massa Filtrat = 128.8184 kg/jam
= 1182.8026 lb/jam

$$\text{Rate Volumetrik} = \frac{\text{Rate Massa}}{\text{Densitas}}$$

$$= \frac{1182.8026 \text{ lb/jam}}{83.8561 \text{ lb/cuft}}$$

$$= 14.1051 \text{ cuft/jam}$$

Waktu tinggal = 7 hari

Volume flok = Rate volumetrik x waktu tinggal

= 14.1051 x 7 x 24

= 2369.6645 cuft

Dirancang volume bak terisi 80% air

$$\text{Volume bak} = \frac{2369.6645}{80\%}$$

= 2962.0806 cuft

Asumsi:

Lebar Bak = Kedalaman Bak = (L = H) H = x ft

L = x ft

Panjang Bak= 3 x Lebar Bak = (P = 3 x L) P = 3 x ft

Volume bak = P x L x H

2962.0806 = 3 x 1 x 1

2962.0806 = 3 x^3

x^3 = 987.3602

x = 9.9577

Panjang = 29.8731 ft

Lebar = 9.9577 ft

Tinggi = 9.9577 ft

<u>Tinggi flok dalam tangki</u>

Volume flok = P x L x Tflok

2369.6645 = 29.8731 x 9.9577 x Tflok

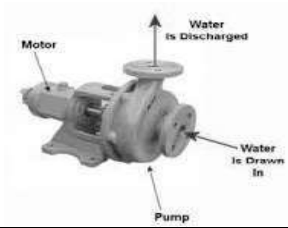
Tflok = 7.9662 ft

Spesifikasi bak penampung flok:

Fungsi	:	Menampung cake dari filter press		
Type	:	Bak berbentuk persegi panjang		
Kapasitas	:	2962.0806 m^3		
Waktu tinggal	:	7 hari		
Ukuran	:	Panjang	= 29.8731	ft
		Lebar	= 9.9577	ft
		Tinggi	= 9.9577	ft
Bahan konstruksi	:	Beton		
Jumlah	:	1 buah		

25 POMPA-5 (L-311)

Fungsi : Mengalirkan oleamida dari filter pres ke filter mmixer
Type : Centrifugal pump
Dasar Pemiliha : Sesuai dengan viskositas < 10 cP dan bahan liquid



Komponen	Massa (kg/jam)	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO_2(l)$	3955.4795	0.9381	0.94
$C_{18}H_{34}O_2(l)$	208.9240	0.0495	0.89
$CO(NH_2)_2(s)$	0.4490	0.0001	1.32
$AlCl_3(s)$	0.4221	0.0001	2.48
$H_2O(l)$	51.1871	0.0121	1
Total	4216.4616	1.0000	6.63

Rate massa = 4216.46 kg/jam
= 9295.70 lb/jam
ρ campuran = 59.58 lb/cuft

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

$$= \frac{9295.7\ \text{lb/jam}}{59.5769\ \text{lb/cuft}}$$

= 156.029 cuft/jam
= 2.6005 cuft/mnt
= 0.0433 cuft/s
= 19.4542 gpm

Asumsi aliran turbulen

Di optimum untuk aliran turbulen, Nre > 2100, digunakan persamaan :

$Di_{opt} = 3.9 \times qf^{0,45} \times \rho^{0,13}$ **(Peters, 4 ed, pers.15 : 496)**

Dengan :

Di opt = diameter optimum ; in
qf = fluid flow rate ; cuft/s
ρ = fluid density ; lb/cuft

$Di_{opt} = 3.9 \times 0.2436 \times 1.7012$

= 1.6160 in

Dipilih pipa 8 in, sch 80 **(Mc Cabe, 5ed, App.5)**

OD = 8.6 in

ID = 7.6 in = 0.6354 ft = 0.194 m

A = 1/4 x π x ID^2

= 0.317 ft²

$$\text{Kecepatan aliran} = \frac{\text{Rate Volumetrik}}{\text{Area Pipa}}$$

$$= \frac{0.0433 \text{ cuft/s}}{0.31694716 \text{ ft}^2}$$

= 0.1367 ft/s

ρ reference = 62.43 lb/cuft

Sg reference = 1 lbf/lbm **(Kern, T. 6, Pg. 808)**

μ reference = 0.00085 lb/ft.s **(Kern, fig. 4, pg. 823)**

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

$$= \frac{59.5769}{62.43}$$

= 0.9543

Viskositas Campuran

T = 30 °C = 303.2 K

$$Log_{10}\,\mu = A + \frac{B}{T} + CT + DT^2 \qquad \mu\ Campuran = \sum_{i}^{n} \mu.Xf$$

Data Viskositas Liquid (Yaws, table 22-2)

Komponen	A	B	C	D	μ (cP)
C18H34O2(l)	-6.1303	1689.3	0.008372	-6.5E-06	**1.260185177**
H2O	-10.2158	1792.5	0.01773	-1.3E-05	**0.815034472**
C18H35NO(l)	-5.475	1564.3	0.00843	-6.9E-06	**1.572672382**

Komponen	Fraksi berat	μ mix (cP)
C18H34O2(l	0.0495	0.06244167
H2O	0.0121	0.00989437
C18H35NO(	0.9381	1.47533025
Total	**0.9998**	**0.07233604**

μ liq mix = 4.9E-05 lb/ft.s

Perhitungan Viskositas Slurry

$$\mu_m = \mu_L[1 + 2.5\Phi + 10.05\Phi^2 + 0.00273\exp(16.6\Phi)]$$

μr = Viskositas slurry campuran (cp) **(Menon S.E, hal. 606)**

μl = Viskositas liquid (cp)

ϕ = Fraksi slurry = 0.066 % = 0.00066

% solid = 0 % % liquid = 99.98 %
ρ solid = 0.89 ρ liquid = 2.83

Sg mix = 2.83
Cv = 0.066 %

μm = 0.072 [1 + 2.5 x 0.0007 + 10.05 x 0.0000 + 0.00273
exp (16.6 x 0.0007)
= 0.07265 cp
Jadi μ mix = 4.88E-05 lb/ft.s

$$N_{Re} = \frac{D \times v \times \rho}{\mu}$$

$$= \frac{0.635 \times 0.137 \times 59.5769}{0.0000}$$

= 106027 > 2100 (Asumsi turbulen benar)
Dipilih pipa Commercial = 0.000046 m
ε/D = 0.00024
f = 0 **(Geankoplis,3ed,Fig.2.10-3)**
gc = 32.17 ft.lbm/s² lbf

Digunakan persamaan Bernoulli :

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

Perhitungan friksi berdasarkan **Geankoplis 3ed**, Tabel 2.10-1, hal 93

Sambungan / Fitting	Le/D
Elbow standard 90°	35
Gate valve open	9

Panjang ekuivalen suction, Le
Taksiran panjang pipa lur = 40 ft
2 Elbow 90' = 3 x 32 x 0.635 = 61.0000 ft
1 Globe val = 1 x 300 x 0.635 = 190.625 ft
1 Gate valve = 1 x 7 x 0.635 = 4.4479 ft

Panjang total pipa (Le) = 296.0729 ft

Friksi yang terjadi :
1 Friksi karena gesekan bahan dalam pipa

$F_1 = \dfrac{2f \times v^2 \times L}{gc \times D}$ **(Peters 4ed, T.1, Hal. 484)**

$= \dfrac{2 \times 0.006 \times 0.0187 \times 296.0729}{32.174 \times 0.6354}$

$= 0.0032$ ft lbf/lbm

2 Friksi karena kontraksi dari tangki ke pipa

$F_2 = \dfrac{K \times v^2}{2 \times \alpha \times gc}$

K = 0 (A tangki >>>A pi **(Peters 4 ed ,hal. 484)**

α = 1 (untuk aliran turbulen)

$F_2 = \dfrac{0.4 \times 0.0187}{2 \times 1 \times 32}$

$= 0.00012$ ft lbf/lbm

3 Friksi karena ekspansi dari pipa ke tangki

$F_3 = \dfrac{\Delta v^2}{2 \times \alpha \times gc}$ (A1 <<< A2, maka v_1 dianggap = 0) **(Geankoplis 3ed, Eq.2.10-16, Hal. 93)**

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

$= \dfrac{0.019 - 0}{2 \times 1 \times 32}$

$= 0.0003$ ft lbf/lbm

4 Friksi karena Elbow 90° **(Geankoplis 3^ed. 2.10-1 hal 93)**

$F_4 = K_f \times \dfrac{v_1^2}{2}$ **(Geankoplis 3ed, Eq.2.10-16, Hal. 93)**

$= 3 \times 0.8 \times \dfrac{0.0187}{2}$

$= 0.0210$ ft lbf/lbm

5 Friksi karena Gate Valve

$F_5 = K_f \times \dfrac{v_1^2}{2}$ **(Geankoplis 3ed, T. 2.10-1, Hal. 93)**

$= 0.2 \times \dfrac{0.0187}{2}$

$= 0.0016$ ft lbf/lbm

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

$= 0.003 + 1E\text{-}04 + 0 + 0.021 + 0.002$

$= 0.02628$ ft lbf/lbm

P_1 = atm + Ph
= atm + ρ x g/gc x h
= (15 x 144) + (59.58 x 1 x 8.2500)
= 2116.8 + 491.51
= 2608.31 lbf/ft^2

P_2 = 1 atm
= 14.7 lbf/in^2
= 2117 lbf/ft^2

ΔP = P_2 - P_1
= 2117 - 2608
= 491.509 lbf/ft^2

$$\frac{\Delta P}{\rho} = \frac{491.50942}{59.576899} = 8.25 \text{ t lbf/lbm}$$

$$\frac{\Delta v^2}{2 \times \alpha \times gc} = \frac{0.019 - 0}{2 \times 1 \times 32}$$
= 3E-04 ft lbf/lbm

Asumsi : Z_1 = 0.0000 ft
Z_2 = 8.2500 ft

ΔZ = 8.2500 ft
g/gc = 1 lbf/lbm

$$\Delta Z \frac{g}{gc} = 8.25 \times 1$$
= 8.25 ft lbf/lbm

Sehingga :

$$-Wf = \frac{\Delta P}{\rho} + \frac{\Delta Z\, g}{gc} + \frac{\Delta v^2}{2 \times gc \times \alpha} + \Sigma F$$
= 8.2500 + 8.2500 + 3E-04 + 0.0263
= 16.5266 ft lbf/lbm

$$hP = \frac{-Wf \times \text{flowrate (gpm)} \times sg}{3960}$$ **(Perry 7ed, pers. 10-51)**

$$= \frac{16.5266 \times 19.4542 \times 0.954}{3960}$$
= 0.0775 hP

Effisiensi pompa = 0.5 **(Peters 4 ed ; fig 14-37 ; hal 520)**

$$BhP = \frac{hP}{\eta \text{ pompa}}$$
$$= \frac{0.0775}{}$$

52%

= 0.149 hP

Effisiensi moto = 0.8 **(Peters 4 ed; fig 14-38 ; hal 521)**

Power motoı = $\frac{\text{BhP}}{\eta \text{ motor}}$

= $\frac{0.1490}{80\%}$

= 0.1862 hP

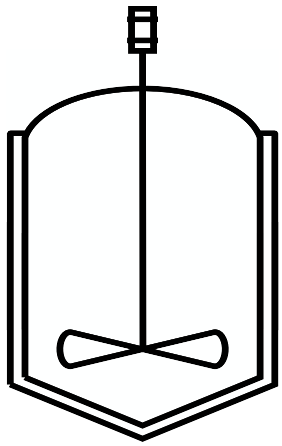
Spesifikasi:

Fungsi	=	Mengalirkan oleamida dari mixer ke filter press
Type	=	Centrifugal pump
Rate volumetri	=	19.45 gpm
Total Dynamic	=	16.53 ft lbf/lbm
BhP	=	0.149 hP
Power Motor	=	0.186 hP
Effisiensi pomı	=	0.5
Effisiensi moto	=	0.8
Bahan konstrul	=	Commercial steel
Jumlah	=	1 buah

23 MIXER (M-310)

Fungsi : Melarutkan campuran oleamida dengan kloroform

Bentuk : Silinder tegak dengan tutup atas torispherical dan bawah conical



Massa Masuk

Komponen	Massa (kg/jam	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO_{(l)}$	3955.47945	0.895258	0.94
$C_{18}H_{34}O_{2(l)}$	208.923994	0.0472865	0.895
$CO(NH_2)_{2(l)}$	0.44900923	0.0001016	1.32
$AlCl_{3(s)}$	0.42206868	9.553E-05	2.48
$CHCl_{3(l)}$	197.773973	0.0447629	1.49
$H_2O_{(l)}$	55.2077631	0.0124954	1
Total	4418.25626	1	8.125

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62.43 \text{ b/cuf}$$

$$= \frac{1}{\frac{0.895}{0.94} + \frac{0.047}{0.895} + \frac{1E-04}{1.32} + \frac{1E-04}{2.48} + \frac{0.045}{1.49} + \frac{0.012}{1}} \times 62.43 \text{ lb/cuft}$$

$$= 59.58 \text{ lb/cuft}$$

Rate Massa = 4418.256 kg/jam

= 9740.488 lb/jam

Rate Volume $= \dfrac{\text{Rate massa}}{\rho \text{ campuran}}$

$= \dfrac{9740.488 \text{ lb/jam}}{59.5769 \text{ lb/cuft}}$

$= 163.4944$ cuft/jam

Asumsi bahan mengisi 80% volume tangki, maka :

Volume tangki $= \dfrac{\text{Volume bahan}}{0.8}$

$= \dfrac{163.4944}{0.8}$

$= 204.368$ cuft

A Menentukan dimensi tangki

Asumsi dimensi ratio = 2 **(Ulrich T.4-27)**

H = 2 D

Volume silinder $= \dfrac{\pi}{4} \times D^2 \times H$

$= 0.785 \times D^2 \times 2\ D$

$= 1.57\ D^3$

Tutup atas dan bawah menggunakan torispherical dished, sehingga :

V tutup atas = $0.000049\ D^3$ (Brownell; pers. 5.11, hal. 88)

V tutup bawah = $0.000049\ D^3$

jika diambil = 30 °

Volume tangki = V silinder + V tutup atas + V tutup bawah

$204.36797 = 1.6\ D^3 + 4.9E\text{-}05\ D^3 + 0.000049\ D^3$

$204.36797 = 1.570098\ D^3$

D^3 = 130.1626		H = 2 D
D = 5.067908 ft		= 10.13582 ft
= 60.81489 in		= 121.6298 in
= 1.544698 m		= 3.089396 m

Menentukan tinggi liquid dalam shell

Volume liquid $= \dfrac{\pi}{4} \times D^2 \times H$

$163.4943725 = 0.785 \times 25.6837 \times H$

$163.4943725 = 20.16169\ H$

H liq = 8.109158 ft

Menentukan Tinggi Tuup Bawah (Conical)

$h = \dfrac{\text{tg } \alpha \times (D - m)}{2}$ **(Hesse, pers 4-17)**

Dengar α = sudut coni = 120 ° 1/2α = 60 °
D = diameter tang (ft)
m = flat sport diamet = 12 in = 1 ft

$$h = \frac{tg\ \alpha \times (D - m)}{2}$$

$$h = \frac{tg\ 120 \times (5.0679 - 1)}{2}$$

h = 3.52291 ft
= 1.07378 m

Menentukan volume conical

volume conical = 0,262 × H × (D^2 + D.m + m^2)
= 0.262 x 3.523 x 31.752
= 29.307 cuft

Menentukan Tekanan Design

P opera = 1 atn = 15 psi

P hidrosta = ρ x g/gc x H_L

$$= 59.58\ \frac{lbm}{cuft} \times 1\ \frac{lbf}{lbm} \times 8.109158\ ft$$

$$= 483.119\ \frac{lbf}{ft^2}$$

= 3.35499 psi

P design = P opera + P hidrostatis
= 14.7 + 3.355
= 18.055 psi

Untuk faktor keamanan, P design dipilih 10% lebih besar

P design = 1.1 x 18.055
= 19.86 psi

Menentukan ketebalan dinding Mixer

Penentuan tebal shell :

$$t_{min} = \frac{P \times ri}{f\ E - 0.6\ P} + C$$

Dimana :

t_{min} = tebal shell mini (in)
P = tekanan tangki (psi)
ri = jari-jari tangki (in; 1/2D)
C = faktor korosi (in: 1/8D) **(Brownell, pg 254)**
E = faktor pengelas (double welde 0.8)
f = Stress allowable, bahan konstruksi Carbon steel SA 167 Grade C,
maka f all = 18750 psi **(Brownell, T.13.1 hal.251)**

Asumsi tebal sł = 0.3 in

$$t_{min} = \frac{P \quad x \quad ri}{f \;\; E \; - \; 0.6 \;\; P} + C$$

$$0.25 = \frac{19.8605 \quad x \quad 30.40745}{f \;\; x \;\; 0.8 \; - \; 0.6 \;\; x \;\; 20} + 0.1$$

$$0.125 = \frac{603.906725}{0.8 \;\; f \; - \; 11.916}$$

$0.1 \;\; f - 1.49 = 603.91$

$0.1 \;\; f = 605.396$

$f = 6053.96$ psi

f hitung lebih kecil dari f *allowable* , jadi tebal shell 1/4 memenuhi

Menentukan Tebal Tutup Atas

Tutup atas dan bawah dipilih torispherical

OD = ID + 2 ts

= 60.81 + 2 (0.25)

= 61.3149 in

Berdasarkan **Tabel 5.7 Brownell** didapatkan :

ts = 0.3

icr = 4.4 in

rc = 72 in

$$\frac{icr}{rc} = 0.1$$

karena icr > 6% rc, maka digunakan persamaan 7.76 dan 7.77

Tebal Tutup Atas (Torispherical Dished)

$$th = \frac{P \quad x \;\; rc \;\; x \;\; W}{2 \;\; f \;\; E \; - \; 0,2 \;\; P} + C$$

Keterangan :

th = tebal head (in)

W = faktor intensifikasi stress

f = Stress allowable, bahan konstruksi Carbon steel SA 167 Grade C,
maka f all = 18750 psi **(Brownell, T.13.1 hal.251)**

C = faktor korosi (iı = 0.13 , 10 tahun
(Tabel 6. Timmerhaus, hal.542)

E = faktor pengelasan digunakan doubl E = 0.8
(Tabel 5-7, Brownell, hal.254)

P = tekanan desain

Faktor Intensifikasi stress (W)

$$W = \frac{1}{4} \text{ x } \left(3 + \sqrt{\frac{rc}{icr}}\right)$$

$$= \frac{1}{4} \text{ x } \quad 3 + \sqrt{\frac{72}{4\ 3/8}}$$

$= 1.764$ in

Sehingga tebal tutup atas :

Asumsi tebal h‹ = 0.2

$$th = \frac{P \text{ x } rc \text{ x } W}{2\ f\ E\ -\ 0{,}2\ P} + C$$

$$0.188 = \frac{14.7 \text{ x } 72 \text{ x } 1.76419}{2 \text{ x } f \text{ x } 0.8 - 0.2 \text{ x } 14.7} + 0.1$$

$$0.063 = \frac{1867.213516}{1.6\ f - 2.94}$$

0.1 f - 0.184 = 1867.214

f = 18674

f hitung lebih kecil dari f *allowable* , jadi tebal tutup atas 3/16 memenuhi

Digunakan tebal head s = 0.188 in

Tebal bott = tebal he = 0.1875 in

untuk tl = 0.188 in, maka sf = 1,5 - 2

(Tabel 5.6. Brownell, hal.88)

Diambil s: = 2

Menghitung tinggi tutup atas (OA)

BC = rc - icr

= 72 - 4.4

= 68 in

$$AB = \frac{1}{2} Di - icr$$

$$= \frac{1}{2} \text{ x } 60.81 - 4.38$$

= 26.03 in

$b = rc - (BC^2 - AB^2)^{0,5}$

$= 72 - (\#\#\# - 678)^{0,5}$

= 9.6 in

Jadi, tinggi tutup adalah

OA = b + sf + t

= 9.6 + 2 + 0.1875

= 11.77 in

= 0.981 ft
= 0.299 m

Tinggi mixer tc = Hs + Hta + Htb
= 10.136 + 0.981 + 3.5229
= 14.64 ft
= 4.4622 m

Tebal Tutup Bawah (Conical)
Sudut con = 60 °
e = 0.8

$$th = \frac{P \times Di}{\cos\alpha\,(f\,E - 0{,}6\,P)} + C$$

$$0.3 = \frac{19.86048859 \times 60.81489107}{2\ \cos 60\ (\ f \times 0.8\ -\ 0.6 \times 19.9\ )} + 0.1$$

$$0.1 = \frac{1207.81345}{1\ \ ((\ f\ \ 0.8\ )\ -\ (\ 11.92\ )}$$

$$0.125 = \frac{1207.81345}{0.8\ \ f\ -\ 11.916}$$

0.1 f - 1.49 = 1207.813
0.1 f = 1206.32
f = 12063.2 psi

f hitung lebih kecil dari f *allowable* , jadi tebal shell 1/4 memenuhi

B. Desain Sistem Pengaduk

Jumlah Baffl = 4
Jumlah Impeller (pengaduk) antara 4 - 16, tetapi umumnya 6 atau 8
Dipilih pengaduk type flat blade turbine dengan jumlah blade 6

Penentuan Dimensi Pengaduk

Tinggi bahan total = 8.1092 ft = 97.31 in
Diameter dalam D = 5.0679 ft = 60.81 in
Ukuran pengaduk diambil dari **MC.cabe ed 7th, hal.247**

$$\frac{Da}{Dt} = \frac{1}{3} \qquad \frac{E}{Dt} = \frac{1}{3} \qquad \frac{W}{Da} = \frac{1}{5}$$

$$\frac{L}{Da} = \frac{1}{4} \qquad \frac{J}{Dt} = \frac{1}{12} \qquad \frac{H}{Dt} = 1$$

Offset 1 = $\frac{1}{2}$Da   Offset 2 = $\frac{1}{6}$ J   **(Wallas,hal 288: 1990)**

Keterangan :
Da = Diameter impeller (pengaduk)

Dt = Diameter tangki
L = Panjang blade
W = Lebar blade
E = Jarak impeller (pengaduk) dari dasar tangki
J = Lebar baffle
Offset 1 = Jarak baffle dari dasar tangki
Offset 2 = jarak baffle dari permukaan cairan

Diameter impeller (Da) = 1/3 = 0.3 x 5.0679
= 1.689 ft
Lebar blade (W) = 1/5 Da = 0.2 x 1.6893
= 0.338 ft
Panjang blade (L)= 1/4 Da = 0.3 x 1.6893
= 0.422 ft
Jarak impeller dari dasar (E) = 0.3 x 5.0679
= 1.689 ft
Lebar baffle (J) = 1/12 Dt = 0.083 x 5.0679
= 0.422 ft
Tebal pengaduk = 0.1 x 0.4223
= 0.042 ft
Offset 1 = 1/2 Da = 0.5 x 1.6893
= 0.845 ft
Offset 2 = 1/6 J = 0.2 x 0.4223
= 0.07 ft
Panjang baff = H_l - (Offset 1 + Offset 2)
= 8.109 - (0.845 + 0.0704)
= 7.194 ft

Penentuan Jumlah Pengaduk

Sg = ∑Fraksi bahan x ρ bahan
Sg = 0.963

$$\text{Jumlah Impeller} = \frac{\text{tinggi liquid x sg}}{\text{Diameter tangki}}$$

$$= \frac{8.1092 \times 0.963}{5.067907589}$$

= 1.5416 ≈ 3 buah
Jarak Pengaduk = 1.5 x Da
= 1.5 x 1.689
= 2.534 ≈ 5 buah

Penentuan Power Motor

Viskositas Campuran

T = 30 °C = 303.2 K

$$Log_{10}\,\mu \;= A + \frac{B}{T} + CT + DT^2 \qquad \mu\,Campuran = \sum_{i}^{n} \mu.Xf$$

Data Viskositas Liquid (Yaws, table 22-2)

Komponen	A	B	C	D	μ (cP)
C18H34O2(	-6.1303	1689.3	0.008372	-6.45E-06	**1.260185177**
H2O	-10.2158	1792.5	0.01773	-1.26E-05	**0.815034472**
C18H35NO(	-5.475	1564.3	0.00843	-6.9E-06	**1.572672382**

Komponen	Fraksi berat	μ mix (cP)
C18H34O2	0.0495496	0.06244167
H2O	0.0121398	0.00989437
C18H35NO	0.938104	1.47533025
Total	**0.9997934**	**0.07233604**

μ liq mix = 4.9E-05 lb/ft.s

Perhitungan Viskositas Slurry

$$\mu_m = \mu_L[1 + 2.5\Phi + 10.05\Phi^2 + 0.00273\,\exp(16.6\Phi)]$$

μr = Viskositas slurry campuran (cp) **(Menon S.E, hal. 606)**

μI = Viskositas liquid (cp)

ϕ = Fraksi slurry = 0.0657 % = 0.00066

% solid = 0 % % liquid = 99.98 %

ρ solid = 0.89 ρ liquid = 1

Sg mix = 0.99997

Cv = 0.023 %

μm = 0.072 [1 + 2.5 x 0.00066 + 10.05 x 4.3E-07 + 0.00273
exp (16.6 x 0.000657)
= 0.07265 cp

Jadi μ mix = 4.88E-05 lb/ft.s

V = π x Da x N **(Joshi, hal.389)**

Dimana :

V = Peripheral speed; m/mnt
Untuk pengaduk jenis turbi 200 - 250 m/mnt

Da = Diameter impeller; = 1.689 ft = 0.5149 m

N = Putaran pengaduk; rpm

Dipilih putaran peng N = 120 rpm = 2 rps

V = π x Da x N

= 3.1 x 0.515 x 120

= 194.014 m/meni **(memenuhi range 200-250 m/menit)**

Bilangan Reynold, Nre :

$$Nre = \frac{\rho \times Da^2 \times N}{\mu}$$

$$Nre = \frac{59.58 \times 2.8537 \times 2}{4.8824E-05}$$

= 6964493.7 > 2100

Untuk NRe > 2100 diperlukan 4 buah baffle sudut 90°

(Perrt 8ed : 18-13)

Power pengaduk :

Untuk NRe > 10.000 perhitungan power menggunakan persamaan berikut

$$P = \frac{Kt}{g} \times \rho \times N^3 \times Da^5$$ **udwig, vol-1, pers 5.5, hal 29**

Keterangan :

P = power ; ft.lb/s

Kt = faktor mixer (tu ; 6.3 **(Ludwig, vol-1, T.5-1, hal 301)**

g = faktor konversi ; 32.2 lbm.ft/lbf/s²

ρ = densitas ; lb/cuft

N = kec.putaran imp ; rps

Da = diameter impell ; ft

$$P = \frac{Kt}{g} \times \rho \times N^3 \times Da^5$$

$$= \frac{6.3}{32} \times 59.58 \times 8 \times 13.7574$$

= 1282.89 lb.ft/s

$$Hp = \frac{P}{550}$$ **dwig, vol-1, Pers.5-6, hal 2**

$$= \frac{1282.89}{550}$$

= 2.33253 hP

Untuk 2 buah impeller, maka powe = jumlah impeller x hP

= 2 x 2.3325289

= 4.665 hP

Perhitungan losses pengaduk

Gland losses (Kebocoran tenaga akibat poros dan bearing) = 0.1

Gland losses 10% = 0.1 x 4.6651
= 0.466506 hP
Power input dengan gland los = 4.665 + 0.466506
= 5.13156 hP
Transmission system losses = 0.2 (Joshi : 424)
= 0.2 x 5.131564
= 1.0263127 hP
Power input dengan transmission syst = 5.13156358 + 1.0263127
= 6.157876 hP
Effisiensi moto = 0.8

$$\text{Sehingga power motor} = \frac{6.157876}{0.8}$$

= 7.697345 hP ≈ 8 hP

C. Sistem Pendingin

Perhitungan jaket pendingin
Sebagai media pendingin digunakan air pe = 30 °C
Untuk menjaga suhu supaya suhu dalam m = 50 °C
Q serap = 201665 kkal/jam
= 799803 Btu/jam
Suhu bahan masuk = 75 °C = 167 °F
Suhu bahan kelua = 35 °C = 95 °F
Air pendingin ma = 30 °C = 86 °F
Air pendingin kel = 45 °C = 113 °F
ΔT1 = 95 °F - 86 °F = 9 °F
ΔT2 = 167 °F - 113 °F = 54 °F

$$\Delta T\ LMTD = \frac{\Delta t2 - \Delta t1}{2.3 \log \frac{\Delta t2}{\Delta t1}}$$

$$= \frac{54 - 9}{2.3 \log \frac{54}{9}}$$

$$= \frac{45}{1.79}$$

= 25.1432 °F

ρ air pendingin = 62.43 lb/cuft

$$\text{Rate Volumetrik} = \frac{799802.504}{62.43}$$

= 12811.1886 cuft/jam
= 3.5586635 cuft/s

Koefisien Perpindahan Panas bagia (Kern page.718 eq. 20-1)

$$hi = 0.4 \ (k/Di) \left[\frac{L^2 \ N \rho}{\mu}\right]^2 \left[\frac{C \mu}{k}\right]^1 \left[\frac{\mu}{\mu_w}\right]^{0,14}$$

Keterangan :

Di = Diameter tangki = 5.068 ft

L = Da (diameter impe = 1.689 ft

N = Putaran Pengaduk = 120 rpm = 7200 rph

ρ = Berat jenis larutan = 0 lb/cuft

μ = Viskositas larutan = 4.882E-05 lb/ft.s

= 0.1757663 lb/ft.jam

= 0.0726618 cP

C = Kapasitas panas campuran

Komponen	Fraksi (Xf)	Cp (kJ/kg K)
$C_{18}H_{35}NO$	0.89525804	1.85
$C_{18}H_{34}O_2$	0.04728653	2
$CO(NH_2)_2$	0.00010163	1.43
$AlCl_3$	9.5528E-05	0.9
$CHCl_3$	0.0447629	0.96
H_2O	0.01249537	4.1813
Total	**1**	

1 kJ/kg = 0.23885 Btu/lb°F

C = %Cp1 + %Cp2 + %Cp3 +…...+%Cpn

= 0.44097 Btu/lb°F

K = Konduktifitas larutan

$$Kmix = \frac{0.0677}{sg\,[\ 1 - 0.0003\ (\ \Delta T\ LM - 32\ )\ ]}$$

$$= \frac{0.0677}{0.963\ [\ 1 - 0.0003\ (\ 25.14 - 32\ )\ ]}$$

= 0.07013 Btu/jam.ft.°F

$$Re\ p = \frac{[\ L^2\ N \rho]}{\mu}^{2/3}$$

$$= \left(\frac{2.854 \times 7200 \times 120}{0.17576634}\right)^{0.7}$$

= 58165

$$\frac{[C\mu]^{1}}{k} = \left(\frac{0.441 \quad x \quad 0.0727}{0.070125721}\right)^{0.3}$$

$= \quad 0.77$

$$\frac{[\mu]^{0,14}}{\mu_w} = \frac{[\quad 0.176 \quad]^{0,14}}{1}$$

$= \quad 0.78395$

$$hi = 0.4 \; x \; \frac{0.07}{5.068} \; x \; 58165.03 \; x \; 0.77 \; x \; 0.78395$$

= 174.951 Btu/jam ft² °F

Koefisien perpindahan panas bagian dalam jaket
bejana :
Dari Kern tabel 10, dipakai pipa 16 BWG dengan ukuran :
OD = 1.5 in **(Kern, Tabel 10 hal.843)**
ID = 1.4 in
A (flow area) = 1.47 in = 0.00094839 m^2
Surface per lin ft (= 0.3925 ft^2

$$v = \frac{W}{\rho \; x \; A} = \frac{13434.6855}{\rho \; x \; A}$$

$$= \frac{13434.68554}{1000 \; kg/m^3 \quad x \quad 0.00094839 \; m^2}$$

= 14165.9 m/jam
= 236.098 m/s
= 774.598 ft/s

hi = 2200 Btu/jam.ft^2.°F **(Kern, Fig.25 hal.835)**

$$hio = hi \; x \; \frac{ID}{OD}$$

$$= 2200 \; x \; \frac{1.37}{1.5}$$

= 2009 Btu/jam.ft^2.°F

$$Uc = \frac{hi \; x \; hio}{hi + hio}$$

$$= \frac{2200 \quad x \quad 2009.3}{2200 \quad + \quad 2009.3}$$

= 1050.1742 Btu/jam ft² °F

Rd = 0.001 **(Kern tabel 12 pg. 845)**

$$\frac{1}{Ud} = \frac{1}{Uc} + Rd$$

$$\frac{1}{Ud} = \frac{1}{1050.17} + 0.001$$

$$\frac{1}{Ud} = 0.002$$

Ud = 512.2 Btu/jam ft² °F

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

$$= \frac{799802.5042}{512.2 \times 25.14321}$$

= 62.1 ft²

Mentukan Tinggi jaket

Tinggi Jaket = Tinggi tangki + Tinggi tutup bawah
= 10.14 + 3.523
= 13.66 ft

Asumsi :

Tebal jaket (tj) = 0.3 in
Tebal air pendingin (s) = 5 in
Effisiensi sambungan la = 0.8
Faktor korosi = 0.1
Bahan konstruksi = Carbon steel SA 167 Grade C
f all = 18750 psi

Do (Shell) = Di + 2 ts
= 60.81 + 2 (0.3)
= 61.31 in
= 5.11 ft

Di (jaket) = Do (Shell) + 2 s
= 61.31 + 2 (5)
= 71.31 in
= 5.943 ft

Do (jaket) = Di (jaket) + 2 tj
= 71.31 + 2 (0.3)
= 71.81 in
= 5.985 ft

Penentuan tebal jaket

P hidrosta = ρ x g/gc x h liq

$$= 62.43 \frac{lbm}{cuft} \times 1 \frac{lbf}{lbm} \times 8.1092 \text{ ft}$$

$$= 506.254752 \frac{lbf}{ft^2}$$

= 3.515658 psi

P jaket = (Pi - Po)jaket
= 19.8605 - 14.7
= 5.16049 psi

P design = P jaket + P hidrostatis
= 5.16049 + 3.516
= 8.67615 psi

Tebal jaket berdasarkan ASME Code untuk cylindrical tank

$$t\ min = \frac{P \times Dij}{2fE - P} + C$$

$$0.25 = \frac{8.67615 \times 71.3148911}{2 \times f \times 0.8 - 8.676} + 0.1$$

$$0.125 = \frac{618.7384487}{1.6\ f - 8.676147}$$

0.2 f - 1.085 = 618.7384
0.2 f = 619.823
f = 3099.11 psi

f all > f design
18750 > 3099.11

Maka, digunakan tj = 0.25 in

Spesifikasi :

Fungsi = Melarutkan campuran oleamida dengan kloroform
Type = Silinder tegak dengan tutup atas torispherical head dan bawah conical dengan dilengkapi pengaduk dan jaket pendingin
Bahan konstruk =
Kapasitas = 163.49 cuft
Jumlah = 1 buah

Dimensi Shell

Diameter shell = 5.0679 inch
Tinggi shell = 10.136 inch
Tebal shell = 0.25 inch

Dimensi Tutup

Tebal tutup ata = 0.1875

Tinggi tutup ata	=	0.9812	
Tebal tutup baw	=	0.25	
Tinggi tutup ba	=	3.5229	

Sistem Pengaduk

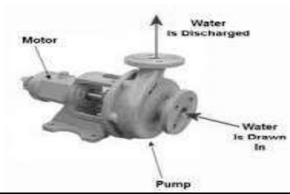
Jenis	=	Tipe flat blade turbin dengan jumlah blade 6 buah	
Jumlah impelle	=	3	
Diameter impel	=	1.6893	ft
Lebar blade	=	0.3379	ft
Panjang blade	=	0.4223	ft
Jarak impeller	=	1.6893	ft
Lebar baffle	=	0.4223	ft
Putaran	=	120	rpm
Power motor	=	8	hP

Jaket Pendingin

Tinggi jacket	=	13.65873	ft
Tebal jacket	=	0.25	in
Diameter jaket	=	5.984574	ft

27 POMPA-6 (L-322)

Fungsi : Mengalirkan campuran oleamida dari mixer press ke evaporator
Type : Centrifugal pump
Dasar Pemiliha : Sesuai dengan viskositas < 10 cP dan bahan liquid



Komponen	Massa (kg/jam	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO_2(l)$	3955.4795	0.469052	0.94
$C_{18}H_{34}O_2(l)$	208.92399	0.0247748	0.89
$CO(NH_2)_2(s)$	0.4490092	5.3245E-05	1.32
$AlCl_3(s)$	0.4220687	5.005E-05	2.48
$CHCl_3(l)$	51.187052	0.00606991	1.49
$H_2O(l)$	4216.4616	0.5	1
Total	8432.9232	1	8.12

Rate massa = 8432.92 kg/jam
= 18591.4 lb/jam
ρ campuran = 58.5864 lb/cuft

Rate volumetri $= \dfrac{\text{Rate massa}}{\rho \text{ campuran}}$

$= \dfrac{18591.4 \text{ lb/jam}}{58.5864 \text{ lb/cuft}}$

= 317.333 cuft/jam
= 5.28889 cuft/mnt
= 0.08815 cuft/s
= 39.5662 gpm

Asumsi aliran turbulen

Di optimum untuk aliran turbulen, Nre > 2100, digunakan persamaan :

$Di_{opt} = 3.9 \times qf^{0,45} \times \rho^{0,13}$ **(Peters, 4 ed, pers.15 : 496)**

Dengan :

Di opt = diameter optimum ; in
qf = fluid flow rate ; cuft/s
ρ = fluid density ; lb/cuft

Di_{opt} = 3.9 x 0.335232 x 1.69751
= 2.21934 in

Dipilih pipa 10 in, sch 80 **(Mc Cabe, 5ed, App.5)**

OD = 11 in

ID = 9.6 in = 0.7968 ft = 0.243 m

A = 0.3 x π x ID^2
= 0.498 ft^2

$$\text{Kecepatan aliran} = \frac{\text{Rate Volumetrik}}{\text{Area Pipa}}$$

$$= \frac{0.08814809 \text{ cuft/s}}{0.49843054 \text{ ft}^2}$$

= 0.17685131 ft/s

ρ reference = 62.43 lb/cuft

Sg reference = 1 lbf/lbm

μ reference = 0.00085 lb/ft.s

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

$$= \frac{58.5864}{62.43}$$

= 0.93843

Viskositas Campuran

T = 30 °C = 303.2 K

$$Log_{10}\,\mu = A + \frac{B}{T} + CT + DT^2 \qquad \mu\ Campuran = \sum_{i}^{n} \mu . Xf$$

Data Viskositas Liquid (Yaws, table 22-2)

Komponen	A	B	C	D	μ (cP)
C18H34O2(l)	-6.1303	1689.3	0.008372	-6.5E-06	**1.260185177**
H2O	-10.2158	1792.5	0.01773	-1.3E-05	**0.815034472**
CHCl3	-4.7831	699.02	0.010929	-1.2E-05	**0.513640058**
C18H35NO(l)	-5.475	1564.3	0.00843	-6.9E-06	**1.572672382**

Komponen	Fraksi berat	μ mix (cP)
C18H34O2	0.0247748	0.03122084
H2O	0.5	0.40751724
CHCl3	0.0060699	0.00311775
C18H35NO	0.469052	0.73766512
Total	**0.9998967**	**0.44185582**

μ liq mix = 0.0003 lb/ft.s

Perhitungan Viskositas Slurry

$$\mu_m = \mu_L[1 + 2.5\Phi + 10.05\Phi^2 + 0.00273\exp(16.6\Phi)]$$

μr = Viskositas slurry campuran (cp) **(Menon S.E, hal. 606)**
μl = Viskositas liquid (cp)
ϕ = Fraksi slurry = 0.012 % = 0.00012

% solid = 0.010329 % % liquid = 99.99 %
ρ solid = 3.8 ρ liquid = 4.32

Sg mix = 4.31994
Cv = 0.012 %

μm = 0.442 [1 + 2.5 x 0.00012 + 10.05 x 1.4E-08 + 0.00273
exp (16.6 x 0.000117)
= 0.44319 cp
Jadi μ mix = 0.000298 lb/ft.s

$$N_{Re} = \frac{D \times v \times \rho}{\mu}$$

$$= \frac{0.797 \times 0.177 \times 58.5864}{0.000297827}$$

= 27720.999 > 2100 (Asumsi turbulen benar)
Dipilih pipa Commercial s = 4.6E-05 m
ε/D = 0.00019
f = 0 **(Geankoplis,3ed,Fig.2.10-3)**
gc = 32.17 ft.lbm/s² lbf

Digunakan persamaan Bernoulli :

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

Perhitungan friksi berdasarkan **Geankoplis 3ed**, Tabel 2.10-1, hal 93

Sambungan / Fitting	Le/D
Elbow standard 90°	35
Gate valve open	9

Panjang ekuivalen suction, Le
Taksiran panjang pipa lur = 40 ft
2 Elbow 90' = 3 x 32 x 0.797 = 76.496 ft
1 Globe val = 1 x 300 x 0.797 = 239.05 ft
1 Gate valv = 1 x 7 x 0.797 = 5.57783 ft

Panjang total pipa (Le) = 361.1238 ft

Friksi yang terjadi :

1 Friksi karena gesekan bahan dalam pipa

$$F_1 = \frac{2f \times v^2 \times L}{gc \times D}$$ **(Peters 4ed, T.1, Hal. 484)**

$$= \frac{2 \times 0.006 \times 0.031276 \times 361.124}{32.174 \times 0.7968}$$

$= 0.00529$ ft lbf/lbm

2 Friksi karena kontraksi dari tangki ke pipa

$$F_2 = \frac{K \times v^2}{2 \times \alpha \times gc}$$

K = 0 (A tangki >>>A pi **(Peters 4 ed ,hal. 484)**

α = 1 (untuk aliran turbulen)

$$F_2 = \frac{0.4 \times 0.031276}{2 \times 1 \times 32}$$

$= 0.00019$ ft lbf/lbm

3 Friksi karena ekspansi dari pipa ke tangki

$$F_3 = \frac{\Delta v^2}{2 \times \alpha \times gc}$$ (A1 <<< A2, maka v_1 dianggap = 0) **(Geankoplis 3ed, Eq.2.10-16, Hal. 93)**

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

$$= \frac{0.031 - 0}{2 \times 1 \times 32}$$

$= 0.00049$ ft lbf/lbm

4 Friksi karena Elbow 90° **(Geankoplis 3^{ed}. 2.10-1 hal 93)**

$$F_4 = K_f \times \frac{v_1^2}{2}$$ **(Geankoplis 3ed, Eq.2.10-16, Hal. 93)**

$$= 3 \times 0.8 \times \frac{0.0313}{2}$$

$= 0.03519$ ft lbf/lbm

5 Friksi karena Gate Valve

$$F_5 = K_f \times \frac{v_1^2}{2}$$ **(Geankoplis 3ed, T. 2.10-1, Hal. 93)**

$$= 0.2 \times \frac{0.031}{2}$$

$= 0.00266$ ft lbf/lbm

$\Sigma F = F_1 + F_2 + F_3 + F_4 + F_5$
$= 0.005 + 2E\text{-}04 + 0 + 0.035 + 0.003$
$= 0.04381$ ft lbf/lbm

P_1 = atm + Ph
= atm + ρ x g/gc x h
= (15 x 144) + (58.59 x 1 x 5.289)
= 2116.8 + 309.9
= 2426.66 lbf/ft²

P_2 = 1 atm
= 14.7 lbf/in²
= 2117 lbf/ft²

$\Delta P = P_2 - P_1$
= 2117 - 2427
= 309.857 lbf/ft²

$$\frac{\Delta P}{\rho} = \frac{309.85652}{58.586354} = 5.2889 \text{ t lbf/lbm}$$

$$\frac{\Delta v^2}{2 \times \alpha \times gc} = \frac{0.031 - 0}{2 \times 1 \times 32}$$
= 5E-04 ft lbf/lbm

ΔZ = 8.25 ft
g/gc = 1 lbf/lbm

$$\Delta Z \frac{g}{gc} = 8.25 \times 1$$
= 8.25 ft lbf/lbm

Sehingga :

$$-Wf = \frac{\Delta P}{\rho} + \frac{\Delta Z\, g}{gc} + \frac{\Delta v^2}{2 \times gc \times \alpha} + \Sigma F$$
= 5.28889 + 8.25 + 5E-04 + 0.04381
= 13.5832 ft lbf/lbm

$$hP = \frac{-Wf \times \text{flowrate (gpm)} \times sg}{3960}$$ **(Perry 7ed, pers. 10-51)**

$$= \frac{13.5832 \times 39.56615 \times 0.938}{3960}$$
= 0.12736 hP

Effisiensi pompa = 0.3 **(Peters 4 ed ; fig 14-37 ; hal 520)**

$$BhP = \frac{hP}{\eta \text{ pompa}}$$

$$= \frac{0.12736}{0.3}$$

$$= 0.42453 \text{ hP}$$

Effisiensi moto = 0.8 **(Peters 4 ed; fig 14-38 ; hal 521)**

$$\text{Power motor} = \frac{\text{BhP}}{\eta \text{ motor}}$$

$$= \frac{0.42453}{0.84}$$

$$= 0.5054 \text{ hP}$$

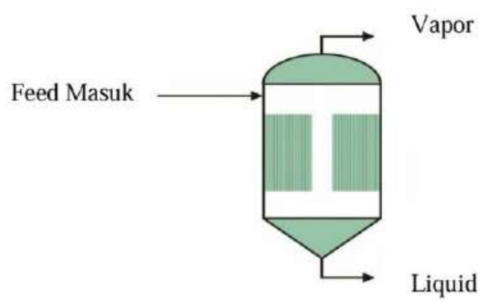
Spesifikasi:

Fungsi	=	Mengalirkan campuran oleamida dari filter press ke evaporator
Type	=	Centrifugal pump
Rate volumetril	=	39.57 gpm
Total Dynamic	=	13.58 ft lbf/lbm
BhP	=	0.425 hP
Power Motor	=	0.505 hP
Effisiensi pomp	=	0.3
Effisiensi moto	=	0.8
Bahan konstruk	=	Commercial steel
Jumlah	=	1 buah

28. EVAPORATOR (V-330)

Fungsi : Menguapkan klorofom dan air sebelum masuk ke dalam crystalizer

Tipe : Asumsi Double Pipe Heat Exchanger (DPHE)



1. Mennetuka Tipe Vaporizer

Komponen Masuk Vaporizer

Komponen	Iassa Masuk (kg/jan	n (kmol/jam
$C_{18}H_{35}NO_{(l)}$	3955.4795	14.0764
$C_{18}H_{34}O_{2(l)}$	208.9240	0.7409
$CO(NH_2)_{2(s)}$	0.4490	0.0075
$AlCl_{3(s)}$	0.4221	0.0032
$CHCl_{3(l)}$	199.7717	1.6620
$H_2O_{(l)}$	131.6128	3.0671
Total	**4496.6590**	**19.5570**

m = 4496.66 kg/jam
= 9913.424 lb/jam

Pre Heating

t1 = 30 °C = 86 °F = 303 K
t2 = 70 °C = 158 °F
tav = 122.1 °F

Vaporizing

t1 = 57 °C = 135 °F
t2 = 70 °C = 158 °F
tav = 147 °F

Fluida Panas (Steam)

M = 220.2601 kg/jam
= 485.5853 lb/jam

T1 = 148 °C = 298 °F
T2 = 148 °C = 298 °F

Heat Balance

Q preheating	=	99911.1	=	396479	Btu/jam
Q Vaporizing	=	45.23	=	179.476	Btu/jam
Kebutuhan Pemanas (Q s)	=	93149.9	=	369649	Btu/jam

Penentuan ΔLMTD

Preheating

Fluida Panas	Fluida Dingin	ΔT	
298.4	158.18	140.22	Δt2
298.4	86	212.4	Δt1
		-72.18	Δt2-Δt1

$$\Delta T \text{ LMTD Prehea} = \frac{\Delta t2-\Delta t1}{\ln(\Delta t2/\Delta t1)} = \frac{-72.18}{\ln(\;140\;/\;212\;)}$$

$$= 173.819 \;°F$$

$$\text{Head Load} = \frac{Qp}{\Delta T}$$

$$= \frac{396479}{173.819} = 2280.99 \text{ Btu/jam °F}$$

Vaporizing

Fluida Panas	Fluida Dingin	ΔT	
298.4	135.32	163.08	Δt2
298.4	158.18	140.22	Δt1
		22.86	Δt2-Δt1

$$\Delta T \text{ LMTD Prehea} = \frac{\Delta t2-\Delta t1}{\ln(\Delta t2/\Delta t1)} = \frac{22.86}{\ln(\;163\;/\;140\;)}$$

$$= 151.362 \;°F$$

$$\text{Head Load} = \frac{Qp}{\Delta T}$$

$$= \frac{179.476}{151.362} = 1.18574 \text{ Btu/jam °F}$$

$$\text{Weighted } \Delta T = \frac{Qs}{\text{head lot total}}$$

$$= \frac{369649}{325.182} = 1137 \;°F$$

Suhu kalorik (suhu rata-rata)

Preheating $tc = \frac{(158 + 86)}{2} = 122.1$ °F

Vaporizing $tc = \frac{(158 + 135.32)}{2} = 146.8$ °F

Fluida Panas $Tc = \frac{(298 + 298.4)}{2} = 298.4$ °F

Menentukan Ud

Komponen Masuk Vaporizer

Komponen	Iassa Masuk (kg/jan	xi
$C_{18}H_{35}NO_{(l)}$	3955.4795	0.8796
$C_{18}H_{34}O_{2(l)}$	208.9240	0.0465
$CO(NH_2)_{2(s)}$	0.4490	0.0001
$AlCl_{3(s)}$	0.4221	0.0001
$CHCl_{3(l)}$	199.7717	0.0444
$H_2O_{(l)}$	131.6128	0.0293
Total	4496.6590	1

Data Viskositas Yaws

Komponen	A	B	C	D	μ	μ.xi
Oleamida	-3.590	1346.500	0.00291	-2.8E-06	30.2122	26.6
Asam Oleat	-6.130	1689.300	0.00837	-6.5E-06	24.4298	1.14
Kloroform	-4.783	699.020	0.01693	-1.2E-05	33.8500	1.5
air	-10.220	1792.000	0.01773	-1.3E-05	0.8042	0.02
Total						29.2

Nilai Ud light organics dan fluida panas ste (Kern Tabel 8 hal 840)

Ud = 100 - 200 Btu/hr ft^2°F

Trial = 200 Btu/hr ft^2°F

$$A = \frac{Qs}{(Ud \times \Delta t)} = \frac{369648.6}{30272.48} = 12.21 \text{ ft}^2$$

Karena A < 120 ft2 maka digunakan Double Pipe Heat Exchanger (DPHE) agar transfer panas lebih maksimal.

Spesifikasi Vaporizer

Dari Tabel 6.2 Kern, 1950 hal 110 direncanakan digunakan :

Ukuran pipa 2 1/2 x 1 1/4 in IPS

Flow area annulus = 2.63 in^2 (Fluida dingin)

Flow area inner pi = 1.5 in^2 (Steam)

Annulus = 2 1/2

Inner pipe = 1 1/4

Dari Tabel 11 Kern, 1950 hal 844 diperoleh :

Annulus = 2 1/2 in (Sch 40)

OD = 2.89 in = 0.24 ft

ID = 2.47 in = 0.21 ft = D2

at = 2.63 in^2 (Kern 1950 hal 110 Tabel 6.2)

Dari Tabel 11 Kern, 1950 hal 844 diperoleh :

Inner pipe = 1 1/4 in (Sch 40) De = 0.004283

OD = 1.66 in = 0.14 ft = D1

ID = 1.38 in = 0.12 ft = D

at = 1.5 in^2 (Kern 1950 hal 110 Tabel 6.2)

Menentukan Koefisien Perpindahan Panas

Annulus	Inner pipe
Fluida Dingin	Fluida Panas (steam)
Menentuka Reynolds Number	**Menentuka Reynolds Number**
$D_2 = \frac{2.469}{12} =$ 0.21 ft	$D = \frac{1.38}{12} =$ 0.115 ft
$D_1 = \frac{1.66}{12} =$ 0.14 ft	
Flow Area (aa)	**Flow Area (aa)**
$a_a = \frac{\pi \; (D_2^2 - D_1^2)}{4}$	$aa = \frac{\pi \; (D^2)}{4}$
= 0.01821 ft^2	= 0.01038 ft^2
Equivalent Diameter (De)	
(Pers. 6.3 Kern, 1950)	
$D_e = \frac{(D_2^2 - D_1^2)}{D_1}$	
= 0.167689 ft	

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Mass Velocity (Ga)

$Ga = \dfrac{m}{a_s} = \dfrac{9913.33\ \text{lb/jam}}{0.01821\ \text{ft}^2}$

$= 544401.3\ \text{lb/jam ft}^2$

Reynolds Number (Rea)

Pada tc = 134 °F

μ_{mix} = 29.2 cp

= 0.02 lb/jam ft^2

$Re_a = \dfrac{De \times Ga}{\mu}$

$= \dfrac{0.167689 \times 544401}{0.01965}$

= 4646195 (Turbulen)

Menentukan Koefisien Film Panas (ho)

(Fig. 24 Kern, 1950 hal 834)

jh = 1000

kmix = 0,080 Btu/jam ft.°F

Cp_{mix} = 1 Btu/lb.°F

μ_{mix} = 29.2386 cp

= 0.01965 lb/jam ft2

Nilai $(\mu/\mu_w)^{0.14}$ = 1

$$ho = JH\left(\frac{k}{De}\right)\left(\frac{cp.\mu}{k}\right)^{1/3} . \left(\frac{\mu}{\mu w}\right)^{0.14}$$

= 2291.66667 Btu/jam ft.°F

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Mass Velocity (Ga)

$Gp = \dfrac{m}{a_s} = \dfrac{485.5853\ \text{lb/jam}}{0.010382\ \text{ft}^2}$

$= 46773.5\ \text{lb/jam ft}^2$

Reynolds Number (Rep)

Pada tc = 298.4 °F

μ_{mix} = 0.024 cp

= 2E-05 lb/jam ft^2

$Re = \dfrac{D \times Gp}{\mu}$

$= \dfrac{0.115 \times 46773.5}{1.61E-05}$

= 3.3E+08 (Turbulen)

Menentukan Koefisien Film Panas (hio)

hio = 1500 Btu/jam ft.°F

(Kern, 1950, Hal. 164)

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Mencari Tahana Panas Pipa Bersih (U_C)

$U_C = \dfrac{ho \times hio}{ho + hio}$

$= \dfrac{2291.667 \times 1500}{2291.667 + 1500}$

= 906.5934 Btu/jam ft^2.°F

Mencari Tahanan Panas Pipa Bersih (U_C)

$$\frac{1}{U_D} = \frac{1}{U_C} + Rd$$

$$\frac{1}{U_D} = \frac{1}{907} + 0.00461$$ (ketentuar (Coulson, Tabel 12.2 Hal 516)

$$\frac{1}{U_D} = 0.00571303$$

U_D = 175.038 Btu/jam ft2.°F

Luas Permukaan yang diperlukan

$$A = \frac{Q}{(Ud \times \Delta t)} = \frac{369649}{26494.2} = 13.95 \text{ ft}^2$$

Hairpin yang digunakan (Tabel 11, Kern hal 844)

Surface per lin ft = 0.753 ft^2/ft

Panjang yang dibutuhkan = $\frac{A}{\text{Surface per lin ft}}$ = 18.52859919 ft

Asumsi panjang pipa 5 ft (kern, Tabel 11)

Jumlah hairpin = $\frac{L}{2.\ L\ pipa}$ = 1.85286 ≈ 1

1 hairpins 5 ft dengan susunan seri

Koreksi Harga A dan UD

Harga A aktual = 5 ft x 0.753 ft^2/ft
= 3.765 ft^2

$$Ud = \frac{Q}{A \times \Delta T} = \frac{369648.5799}{3.765 \times 151.362} = 648.6435 \text{ Btu/jam ft2.°F}$$

$$Rd = \frac{(Uc - Ud)}{(Uc \times Ud)} = \frac{(906.593 - 648.643)}{(906.593 \times 648.643)} = 0.00044$$ (Rd hitumg dibawah Rd ketentuan)

Evaluasi Pressure Drop (ΔP)

Annulus	Inner pipe
Fluida Dingin	Fluida Panas (Steam)
Menentukan Re dan Friksi	**Menentukan Re dan Friksi**
$D_e' = (D_2-D_1)$	Untuk Nre = 3.34E+08
$= 0.06742$ ft	
$NRe = \dfrac{De' \times Ga}{\mu}$	
$= \dfrac{0.06742 \times 544401}{29.2386}$	
$= 74597$	
(Kern,1965, Pers 3.47b, Hal 53)	
$f = 0.0035 + \dfrac{0.0035}{(Nre)^{0.42}}$	$f = 0.0035 + \dfrac{0.0035}{(Nre)^{0.42}}$
$= 0.0035 + \dfrac{0.0035}{(Nre)^{0.42}}$	$= 0.0035 + \dfrac{0.0035}{(Nre)^{0.42}}$
$= 0.003531$ lb/ft^3	$= 0.003501$ lb/ft^3
(Kern,1965, Hal 808.Tabel 6)	(Kern,1965, Hal 808.Tabel 6)
s mix = 2.49	s H2O = 1
$\rho = 62.5 \times 2.49$	$\rho = 62.5 \times 1$
$= 156$ lb/ft^3	$= 62.5$ lb/ft^3
Menentukan ΔP panjang pipa	**Menentukan ΔP panjang pipa**
(Kern,1965, Pers 3.44, Hal 52)	(Kern,1965, Pers 3.44, Hal 52)
$\Delta F_s = \dfrac{4 \cdot f \cdot G_a^2 \cdot L}{2 \cdot g \cdot \rho \cdot De'}$	$\Delta F_p = \dfrac{4 \cdot f \cdot G_a^2 \cdot L}{2 \cdot g \cdot \rho \cdot De'}$
$= 0.01534$ ft	$= 0.000408$ ft
(Kern,1965, Hal 115)	
$V = \dfrac{Ga}{3600 \times \rho}$	
$= \dfrac{544401}{3600 \quad 155.625}$	
$= 0.97171$ fps	

(Kern,1965, Hal 115) $Ft = 3\left(\frac{V^2}{2\,g}\right)$ = 0.04399 ft	
(Kern,1965, Hal 115) $\Delta P_L = \frac{(\Delta F + Ft) \times \rho}{144}$ = 0.04764 psi	(Kern,1965, Hal 115) $\Delta P_L = \frac{(\Delta Fs + Ft) \times \rho}{144}$ = 0.000177 psi
Memenuhi pressure drop ketentuan 10 psi (Ker 1965, hal 840)	Memenuhi pressure drop ketentuan 2 psi (Kern 1965, hal 840)

Spesifikasi :

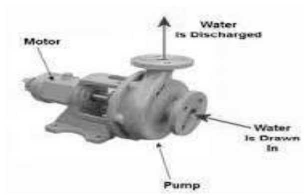
Fungsi	=	Menguapkan Klorofrom dan Air sebelum masuk k dalam Crystalizer
Type	=	Double Pipe Heat Exchanger (DPHE)
ID Annulus	=	2 1/2 in
OD annulus	=	2 8/9 in
ID inner pipe	=	1.38 ft
OD inner pipe	=	1.66 in
Jumlah Hairpin	=	1 buah
L hairpin	=	5 ft

29 POMPA-7 (L-331)

Fungsi : Mengalirkan campuran oleamida dari evaporator ke crystalizer

Type : Centrifugal pump

Dasar Pemiliha : Sesuai dengan viskositas < 10 cP dan bahan liquid



Komponen	Massa (kg/jam	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO_2(_l)$	3955.47945	0.93823544	0.94
$C_{18}H_{34}O_2(_l)$	208.923994	0.04955654	0.89
$CO(NH_2)_2(s)$	0.44900923	0.0001065	1.32
$AlCl_3(_s)$	0.42206868	0.00010011	2.48
$CHCl_3(l)$	39.5547945	0.00938235	1
$H_2O(_l)$	11.0415526	0.00261904	1
Total	4215.87087	1	7.63

Rate massa = 4215.871 kg/jam

= 9294.393 lb/jam

ρ campuran = 155.625 lb/cuft

ate volumetri = $\dfrac{\text{Rate massa}}{\rho \text{ campuran}}$

= $\dfrac{9294.393 \text{ lb/jam}}{155.625 \text{ lb/cuft}}$

= 59.72301 cuft/jam

= 0.995383 cuft/mnt

= 0.01659 cuft/s

= 7.446464 gpm

Asumsi aliran turbulen

Di optimum untuk aliran turbulen, Nre > 2100, digunakan persamaan :

$Di_{opt} = 3.9 \times qf^{0,45} \times \rho^{0,13}$ **(Peters, 4 ed, pers.15 : 496)**

Dengan :

Di opt = diameter optimum ; in

qf = fluid flow rate ; cuft/s

ρ = fluid density ; lb/cuft

Di_{opt} = 3.9 x 0.1580985 x 1.92739
= 1.1884 in

Dipilih pipa 8 in, sch 40 **(Mc Cabe, 5ed, App.5)**

OD = 8.6 in

ID = 8 in = 0.6651 ft = 0.203 m

A = 0.3 x π x ID^2
= 0.347 ft^2

$$\text{Kecepatan aliran} = \frac{\text{Rate Volumetrik}}{\text{Area Pipa}}$$

$$= \frac{0.016589725 \text{ cuft/s}}{0.347233635 \text{ ft}^2}$$

= 0.047776837 ft/s

ρ reference = 62.43 lb/cuft

Sg reference = 1 lbf/lbm

μ reference = 0.00085 lb/ft.s

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

$$= \frac{155.625}{62.43}$$

= 2.492792

Viskositas Campuran

T = 30 °C = 303.15 K

$$Log_{10}\,\mu = A + \frac{B}{T} + CT + DT^2 \qquad \mu\ Campuran = \sum_{i}^{n} \mu . Xf$$

Data Viskositas Liquid (Yaws, table 22-2)

Komponen	A	B	C	D	μ (cP)
C18H34O2(	-6.1303	1689.3	0.008372	-6.5E-06	**0.256801241**
H2O	-10.2158	1792.5	0.01773	-1.3E-05	**0.443274747**
CHCl3	-4.7831	699.02	0.010929	-1.2E-05	**0.384807943**
C18H35NO(	-5.475	1564.3	0.00843	-6.9E-06	**0.3132634**

Komponen	Fraksi berat	μ mix (cP)
C18H34O2	0.04955654	0.01272618
H2O	0.00261904	0.00116096
CHCl3	0.00938235	0.0036104
C18H35NO	0.93823544	0.29391482
Total	**0.99979338**	**0.01749754**

μ liq mix = 1.18E-05 lb/ft.s

Perhitungan Viskositas Slurry

$$\mu_m = \mu_L[1 + 2.5\Phi + 10.05\Phi^2 + 0.00273\exp(16.6\Phi)]$$

μr = Viskositas slurry campuran (cp) **(Menon S.E, hal. 606)**
μI = Viskositas liquid (cp)
ϕ = Fraksi slurry = 0.118 % = 0.00118

% solid = 0 % % liquid = 99.98 %
ρ solid = 2 ρ liquid = 11.43

Sg mix = 11.41888
Cv = 0.118 %

μm = 0.017 [1 + 2.5 x 0.00118 + 10.05 x 1.4E-06 + 0.00273
exp (16.6 x 0.0011797)
= 0.0176 cp
Jadi μ mix = 1.183E-05 lb/ft.s

$$N_{Re} = \frac{D \times v \times \rho}{\mu}$$

$$= \frac{0.665 \times 0.0478 \times 155.625}{1.18259E-05}$$

= 418155.355 > 2100 (Asumsi turbulen benar)
Dipilih pipa Commercial st = 4.6E-05 m
ε/D = 0.00023
f = 0 **(Geankoplis,3ed,Fig.2.10-3)**
gc = 32.17 ft.lbm/s² lbf

Digunakan persamaan Bernoulli :

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

Perhitungan friksi berdasarkan **Geankoplis 3ed**, Tabel 2.10-1, hal 93

Sambungan / Fitting	Le/D
Elbow standard 90°	35
Gate valve open	9

Panjang ekuivalen suction, Le
Taksiran panjang pipa luru = 40 ft
2 Elbow 90' = 3 x 32 x 0.665 = 63.848 ft
1 Globe val = 1 x 300 x 0.665 = 199.525 ft
1 Gate valve = 1 x 7 x 0.665 = 4.65558 ft

Panjang total pipa (Le) = 308.0286 ft

Friksi yang terjadi :

1 Friksi karena gesekan bahan dalam pipa

$F_1 = \dfrac{2f \times v^2 \times L}{gc \times D}$ **(Peters 4 ed ,hal. 484)**

$= \dfrac{2 \times 0.007 \times 0.002283 \times 308.029}{32.174 \times 0.6651}$

$= 0.00046$ ft lbf/lbm

2 Friksi karena kontraksi dari tangki ke pipa

$F_2 = \dfrac{K \times v^2}{2 \times \alpha \times gc}$

$K = 0$ (A tangki >>>A pip **(Peters 4 ed ,hal. 484)**

$\alpha = 1$ (untuk aliran turbulen)

$F_2 = \dfrac{0.4 \times 0.0022826}{2 \times 1 \times 32}$

$= 1.4E-05$ ft lbf/lbm

3 Friksi karena ekspansi dari pipa ke tangki

$F_3 = \dfrac{\Delta v^2}{2 \times \alpha \times gc}$ (A1 <<< A2, maka v_1 dianggap = 0)

(Geankoplis 3ed. 2.10-1 hal 93)

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

$= \dfrac{0.002 - 0}{2 \times 1 \times 32}$

$= 3.5E-05$ ft lbf/lbm

4 Friksi karena Elbow 90° **(Geankoplis 3ed. 2.10-1 hal 93)**

$F_4 = K_f \times \dfrac{v_1^2}{2}$ **(Geankoplis 3ed, Eq.2.10-16, Hal. 93)**

$= 3 \times 0.8 \times \dfrac{0.0023}{2}$

$= 0.00257$ ft lbf/lbm

5 Friksi karena Gate Valve

$F_5 = K_f \times \dfrac{v_1^2}{2}$ **(Geankoplis 3ed, T. 2.10-1, Hal. 93)**

$= 0.2 \times \dfrac{0.0023}{2}$

$= 0.00019$ ft lbf/lbm

$\Sigma F = F_1 + F_2 + F_3 + F_4 + F_5$
$= 5E\text{-}04 + 1E\text{-}05 + 4E\text{-}05 + 0.003 + 2E\text{-}04$
$= 0.00327$ ft lbf/lbm

$P_1 =$ atm + Ph
= atm + ρ x g/gc x h
= (15 x 144) + (155.6 x 1 x 0.995)
= 2116.8 + 154.91
= 2271.71 lbf/ft²

$P_2 =$ 1 atm
= 14.7 lbf/in²
= 2117 lbf/ft²

$\Delta P = P_2 - P_1$
= 2117 - 2271.7
= 154.907 lbf/ft²

$\dfrac{\Delta P}{\rho} = \dfrac{154.90655}{155.625} = 0.9954$ t lbf/lbm

$\dfrac{\Delta v^2}{2 \times \alpha \times gc} = \dfrac{0.0023 - 0}{2 \times 1 \times 32}$
$= 4E\text{-}05$ ft lbf/lbm

Asumsi : $Z_1 = 0$ ft
$Z_2 = 4.343748$ ft

$\Delta Z = 4.34375$ ft
g/gc = 1 lbf/lbm

$\Delta Z \dfrac{g}{gc} = 4.344 \times 1$
$= 4.344$ ft lbf/lbm

Sehingga :

$-Wf = \dfrac{\Delta P}{\rho} + \dfrac{\Delta Z\ g}{gc} + \dfrac{\Delta v^2}{2 \times gc \times \alpha} + \Sigma F$
$= 0.99538 + 4.3437 + 4E\text{-}05 + 0.00327$
$= 5.34244$ ft lbf/lbm

$hP = \dfrac{-Wf \times \text{flowrate (gpm)} \times sg}{3960}$
$= \dfrac{5.34244 \times 7.4464638 \times 2.493}{3960}$
$= 0.02504$ hP

Effisiensi pompa = 0.5 **(Peters 4 ed ; fig 14-37 ; hal 520)**

$$BhP = \frac{hP}{\eta\ pompa}$$

$$= \frac{0.025043}{0.52}$$

$$= 0.048159\ hP$$

Effisiensi moto = 0.8 **(Peters 4 ed; fig 14-38 ; hal 521)**

$$\text{Power motor} = \frac{BhP}{\eta\ motor}$$

$$= \frac{0.048159}{0.8}$$

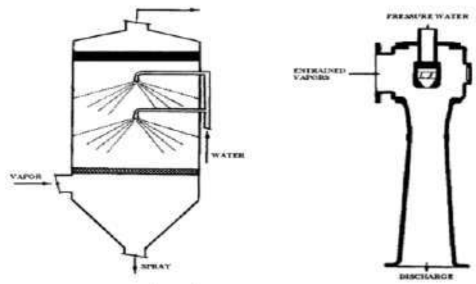
$$= 0.060199\ hP$$

Spesifikasi:

Fungsi	=	Mengalirkan campuran oleamida dari evaporator ke crystalizer
Type	=	Centrifugal pump
Rate volumetril	=	7.4465 gpm
Total Dynamic	=	5.3424 ft lbf/lbm
BhP	=	0.0482 hP
Power Motor	=	0.0602 hP
Effisiensi pomp	=	0.52
Effisiensi moto	=	0.8
Bahan konstruk	=	Commercial steel
Jumlah	=	1 buah

30. KONDENSOR (E-332)

Fungsi : Mengubah fase gas kloroform menjadi liquid
Type : Shell and tube, 1-2 exchanger (Fixed tube)
Kondisi operasi : Tekanan = 1 atm
Suhu = 30 °C



Rate massa = 158.2192 kg/jam
= 348.81 lb/jam

Rate volumetrik $= \frac{\text{Rate massa}}{\text{Densitas}}$
$= \frac{348.81}{155.63}$
= 2.2413 cuft/jam

Perhitungan :

M_{uap}	=	818.3537	kkal/jam
	=	3245.31812	Btu/jam
Panas yang dibutuhkan, Q	=	12498.0332	kkal/jam
	=	49563.0357	Btu/jam
$M_{air\ pendingin}$	=	834.3202	kg/jam
	=	1839.34231	lb/jam

Data dari **Appendix A dan Appendix B** diperoleh :

Suhu bahan masuk	(T_1)	=	61	°C	=	142	°F
Suhu bahan keluar	(T_2)	=	35	°C	=	95	°F
Suhu cooling water masuk	(t_1)	=	30	°C	=	86	°F
Suhu cooling water keluar	(t_2)	=	45	°C	=	113	°F

Δt1 = 46.8
Δt2 = 27

$$\Delta T_{LMTD} = \frac{\Delta t_2 - \Delta t_1}{2.3 \log \frac{\Delta t_2}{\Delta t_1}}$$ **(Kern; Pers. 5.14)**

$$= \frac{27 - 47}{2.3 \log \frac{27}{47}}$$

$$= \frac{-20}{-0.549}$$

$$= 36.037 \ °F$$

$$R = \frac{T1 - T2}{t2 - t1} = \frac{142 - 95}{113 - 86} = 1.733$$

$$S = \frac{t2 - t1}{T1 - t1} = \frac{113 - 86}{141.8 - 86} = 0.4839$$

F_T = 1 **(Kern; Fig. 18)**

Δt = LMTD x F_T (Untuk 1 dan 2 shell and tube)
= 36.037 x 1
= 36.03743 °F

3. Tc dan tc dipakai temperatur rata-rata

Tc = Tav bahan

$$Tc = \frac{T_1 + T_2}{2} = \frac{141.8 + 95.0}{2} = 118.4 \ °F$$

tc = tcav air

$$tc = \frac{t_1 + t_2}{2} = \frac{86 + 113}{2} = 100 \ °F$$

Dipilih tipe : 1 - 2 Heat Exchanger
Digunakan shell and tube dengan ukuran :
OD, BWG = 3/4 in 16 BWG
Pitch = 1 in Square Pitch
Panjang Tube, L = 9 ft

Berdasarkan Kern: T.10, hal.843

ID = 0.62 in
a't = 0.302 in^2
a'' = 0.1623 ft^2/ft panjang

Nilai U_D range = 2-50 Btu/jam.ft^2°F
(Kern T.8, hal.840)

Dipilih U_D = 10 Btu/jam.ft^2°F

$$A = \frac{Q}{\Delta T_{LMTD} \times U_D}$$

$$= \frac{49563.0357}{36.037 \times 10}$$

$$= 137.532118 \ ft^2$$

Jumlah Tube (Nt) $= \frac{A}{L \times a''}$

$$= \frac{138 \ ft^2}{9 \times 0.1623 \ ft}$$

$$= 94.1549 \text{ buah}$$

Asumsi 2 tube passes, dari Kern; tabel 9 diperoleh

Digunakan Nt = 20

ID Shell = 10 in

Phases = 4

Baffle space = 5 in

Koreksi U_D :

A = Nt x L x a''

= 94 x 9 x 0.1623

= 137.5321 ft^2

$$UD = \frac{Q}{A \times \Delta t}$$

$$= \frac{49,563}{137.532 \times 36.037}$$

= 10 Btu/j ft^2°F

Fluida Dingin (Tube side)	Fluida Panas (shell side)
1) Flow area (a't) $at = \frac{Nt \times a't}{144 \ n}$ $= \frac{20 \times 0.3}{144 \times 4}$ = 0.0105 ft^2	1') Flow area (at) C'' = Pt - OD = 0.25 in as = ID x C'B / 144 P_T $= \frac{10 \times 0.25 \times 5}{144 \times 4}$ = 0.0217 ft^2
2) Kecepatan massa (Gt) $Gt = \frac{W}{at}$	2') Kecepatan massa (Gs) $Gs = \frac{W}{as}$

$= \frac{1839.342313}{0.0105}$

$= 175407.479$ lb/jam.ft²

3) Velocity, v

$v = \frac{Gt}{3600 \times \rho}$

$= \frac{175407.4788}{3600 \times 155.6}$

$= 0.31309$ fps

4) Pada Tc = 118.4 °F

$\mu = 0.720 \times 2.42$

$= 1.7424$ lb/ft.jam

$D = \frac{0.62}{12} = 0.0517$ ft

$Re.t = \frac{DGt}{\mu}$

$= \frac{0.05167 \times 175407.4788}{1.7424}$

$= 5,201.2854$

5) Koefisien Perpindahan Panas

hi = 440 Btu/hr ft² °F

(Kern : Fig.25, hal.835)

6) hio

$hio = hi \times \frac{ID}{OD}$

$= 440 \times \frac{0.62}{3/4}$

$= 363.73$ Btu/hr ft² °F

$= \frac{3,245}{0.0217}$

$= 149544.259$ lb/jam.ft²

3') Velocity, v **(Kern, hal.266)**

$G'' = \frac{W\ bahan}{L \times Nt^{2/3}}$

$= \frac{1839.3423}{9 \times 7.368}$

$= 27.73746$ lb/jam lin ft

5') Koefisien Perpindahan Panas

Asumsi :

ho = 100 - 300 Btu/hr ft² °F

Dipilih ho = 300 Btu/hr ft² °F

$tw = tc + \frac{ho}{hic + ho}(Tc - tc)$

$= 100 + \frac{300}{663.73}$ (19

$= 108.0$ °F

$tf = \frac{Tc + tw}{2}$

$= \frac{118.4 + 108}{2}$

$= 113.22$ °F

Berdasarkan tf, didapatkan :

kf = 0.08 Btu/hr ft²

(Kern : T.4, hal.800)

sf = 1.49

	(Kern : T.6, hal.808) μf = 0.3 **(Kern : Fig.14, hal.823)** Dari **Kern Fig.12-9, hal.267**

7) Clean overall coefficient (Uc)

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

$$= \frac{363.73 \times 300}{363.73 + 300}$$

$$= 164.403 \text{ Btu/j ft}^2 \text{ °F}$$

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

$$= \frac{164.403 - 10}{164.403 \times 10}$$

$$= 0.0939 \text{ j ft}^2 \text{ F/BTU}$$

Rd perhitungan > Rd data (Kern ; T 12)

0.0939 > 0.002

maka dari segi faktor kekotoran memenuhi syarat

Pressure drop

Fluida Dingin (Tube side)	Fluida Panas (Shell side)
Re = 5,201.2854 f = 0.00035 $\Delta Pt = \frac{1}{2} \times \frac{f.Gt^2.L.n}{5{,}22 \times 10^{10}.Ds.øt}$ = 0.1410 psi Dari **Kern Fig.27, hal.837** Gt = 175407.479 lb/jam.ft² $\frac{V^2}{2g'} = 0.004$ $\Delta Pr = \frac{4\,n}{s} \times \frac{V^2}{2g'}$ $= \frac{4 \times 4}{1.49} \times 0.004$ = 0.042953	Pada Tc = 118 °F μ vapor = 0.0115 cP = 0.02782 lb/ft.jam **(Kern: Fig.15, hal.825)** N+1 = 12 L / B = 21.6 De = 0.95 in = 0.08 ft **(Kern: Fig.28, hal.838)** Ds = 10 in = 0.833 ft s = 1 $Re's = \frac{de \times Gs}{\mu}$ $= \frac{0.0792 \times 149{,}544}{0.0278}$ = 425561.7081

$\Delta P_T = \Delta Pt + \Delta Pr$ $= 0.141 + 0.04$ $= 0.1839$ psi $\Delta P_T < 10$ psi (memenuhi)	f = 0.0013 ft^2/in^2 **(Kern: Fig.29, hal.839)** $\Delta Ps = \dfrac{f.Gs^2.Ds.(N+1)}{5{,}22 \times 10^{10}.De.s}$ = 0.1266 psi $\Delta Ps < 2$ psi (memenuhi)

Jadi Pi = $\Delta P_T + \Delta Ps$
= 0.1839 + 0.1266
= 0.3106 psi

Spesifikasi :
Shell side

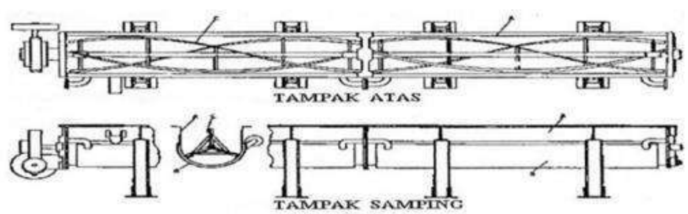
ID	=	10 in
Heat exch, area A	=	137.5321 ft^2
Bahan Konstruksi	=	Carbon Steel
Jumlah	=	1 buah

Tube side

ID	=	0.62 in
OD	=	3/4 in
BWG	=	16
Nt	=	94 buah
L	=	9 ft
Pitch	=	1 in square
Flow area per tube (a't)	=	0.302 in^2
Surface per lin ft (a")	=	0.1623 ft^2

31. CRYSTALIZER (X-340)

Fungsi = Kristalisasi larutan oleamida dengan pendinginan
Type = Swenson-Walker Crystalillizer
Dasar Pemilihan = Umum digunakan untuk kristalisasi dengan pendinginan



Feed masuk crystalizer

Komponen	Massa (kg/jam)	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO_{(l)}$	1.4242807	0.0003	0.94
$C_{18}H_{34}O_{2(l)}$	3954.055171	0.9404	0.895
$CO(NH_2)_{2(s)}$	208.9239943	0.049687	1.32
$AlCl_{3(s)}$	0.449009229	0.000107	2.48
$CHCl_{3(l)}$	0.422068675	0.0001	1.49
$H_2O_{(l)}$	39.55479452	0.0094	1
Subtotal	**4204.829319**	**1**	**7.125**

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62.43 \text{ lb/cuft}$$

$$= \frac{1}{\frac{0.000339}{0.94} + \frac{0.94036}{0.895} + \frac{0.04969}{1.32} + \frac{0.00011}{2.48} + \frac{0.0001}{1.49} + \frac{0.00941}{1}} \times 62.43 \text{ lb/cuft}$$

$$= 56.8475 \text{ lb/cuft}$$

Rate Massa = 4204.829319 kg/jam
= 9269.9667 lb/jam

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

$$= \frac{9269.9667 \text{ lb/jam}}{56.85 \text{ lb/cuft}}$$

$$= 163.0673 \text{ cuft/jam}$$

Waktu kristalisasi = 1 jam

Volume bahan = Rate volumetrik x waktu kristalisasi

= 163.0673 x 1

= 163.0673 cuft

Direncanakan volume bahan mengisi 70% volume crystalizer, maka :

$$\text{Volume crystalizer} = \frac{\text{Volume bahan}}{70\%} = \frac{163.0673}{70\%} = 232.9532 \text{ cuft}$$

digunakan 1 buah crystalizer

Dimensi Crystalizer **(Hugot, Persm, 34.7 Page 733)**

Digunakan dimension ratic m = L/D = 3.33

$$\text{Volume crystalizer} = \frac{m \times D^3}{2} \times \left(1 + \frac{\pi}{4}\right)$$

$$232.9532 = \frac{3.33 \times D^3}{2} \times \left(1 + \frac{\pi}{4}\right)$$

$$232.9532 = 1.6650 \; D^3 \times 1.785$$

$$D = 4.2796 \text{ ft} = 1.3044 \text{ m}$$

$$L = 14.2511 \text{ ft} = 4.34375 \text{ m}$$

Luas Cooling area pada Crystalizer

$$S = V + \frac{(2 + 4m)}{m \times D}$$ **(Hugot, Pers 34.8 Page 733)**

$$= 232.9532 + \frac{2 + (4 \times 3.33)}{3.33 \times 4.2796}$$

$$= 232.9532 + 1.0750$$

$$= 234.0282 \text{ ft}^2/\text{ft}^3$$

Power pengaduk pada Swenson-Walker Crystalizer

Power yang digunakan adalah 16 hp tiap 1000 cuft bahan

Volume bahan = 232.9532 cuft **(Hugot, Page 730)**

$$\text{Power crystalizer} = \frac{232.9532}{1000} \times 16$$

$$= 3.7273 \text{ hp} = 4 \text{ hp}$$

Digunakan pengaduk tipe helix

Kecepatan Pengadukan = 7.00 rpm

Diameter Impeller Helix = $\frac{1}{3}$ x Diameter Crystallizer
= 1.43 ft

Panjang Impeller Helix = 0.25 x Panjang Crystallizer
= 3.56 ft

Menghitung Jaket Pendingin

T air pendingin = 30 °C

Qserap = 52768.01 Kkal/Jam

Kebutuhan Air Pendingin = 3515.35 Kg/Jam
= 7804.07 lb/jam

ρ air pendingin = 62.40 lb/cubft

Kecepatan aliran = 1 ft/s

Luas Penampang (A) = $\frac{\text{Rate Volumetrik}}{\text{Kecepatan Aliran}}$
= 163.0673 ft²

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

Keterangan

D_2 = diameter dalam jaket

D_1 = diameter luar bejana

$$163.0673 = \frac{3.14}{4} \times (D_2^2 - 18.32)$$

D^2 = 15.03 ft

$$\text{Space} = \frac{D_2 - D_1}{2}$$

= 5.38 ft

Penentuan Panjang Jacket

Panjang Jacket = Panjang Crystallizer
= 14.2511 ft

Penentuan Tebal Jacket

P design = Pgauge + Phidrostatik

= 14.7 + ρ g h
= 14.7 + 56.848 x 1 x 9.976
= 18.6 psig

Pdesign dibesarkan 10% untuk keamanan
P design = 18.6382 x 110%
= 20.5020 psig (Tekanan Dalam)

$$t_{min} = \frac{P \times r_i}{f\ E - 0.6\ P} + C$$

Keterangan :

t_{min}	:	tebal shell minimum	(in)		
P	:	Tekanan tangki	(psi)	;	20.502 psi
r_i	:	jari-jari dalam	(in)	;	25.6777 in
f	:	stress maksimum	(psi)	;	
		digunakan SA 283 C Carbon Steel			12650 psi
E	:	Faktor pengelasan		;	Double welded but joint = 0.8
C	:	Faktor korosi		;	1/8

t_{min} = 1/6 in
= 2.83334 /16 in

Maka diambil tebal shell (ts) = 1/6 inch

Spesifikasi :

Fungsi	=	Kristalisasi larutan oleamida dengan pendinginan
Type	=	Swenson-Walker Crystalizer
Dasar pemilihan	=	Umum digunakan untuk kristaalisasi dengan pendinginan
Waktu Operasi	=	1 jam
Kapasitas	=	163.0673 cuft
Diameter	=	4.2796 ft = 1.3044 m
Panjang	=	14.2511 ft = 4.34375 m
Luas Cooling Area	=	234.0282 ft^2/ft^3
Jumlah Crystalizer	=	1 buah

a. Pengaduk
   Power Pengaduk = 4 hp
   Tipe Pengaduk = Helix

Diameter Pengaduk	=	1.43	ft
Panjang Pengaduk	=	3.56	ft

b. Sistem Pendingin

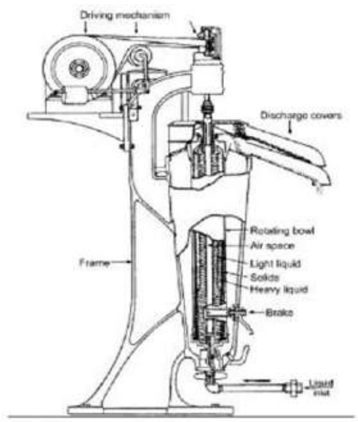
Diameter Jaket	=	15.03	ft
Panjang Jaket	=	14.2511	ft
Jaket Spacing	=	5.38	ft
Tebal Jaket	=	1/6	in

32. CENTRIFUGE (H-350)

Fungsi = Memisahkan kristal oleamida dari motherliquor

Type = Disk Bowls Centrifuge (automatic continous dish cake)

Dasar Pemilihan = Sesuai dengan jenis bahan, effisiensi tinggi



Feed masuk centrifuge :

Komponen	Massa (kg/jam)	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO_{(l)}$	1.4242807	0.0003	0.94
$C_{18}H_{35}NO_{(s)}$	3954.055171	0.9379	0.94
$C_{18}H_{34}O_{2(l)}$	208.9239943	0.0496	0.895
$CO(NH_2)_{2(s)}$	0.449009229	0.000107	1.32
$AlCl_{3(s)}$	0.422068675	0.000100	2.48
$CHCl_{3(l)}$	39.55479452	0.0094	1.49
$H_2O_{(l)}$	11.04155263	0.0026	1
Total	**4215.870871**	**1**	**8.065**

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62.43 \text{ lb/cuft}$$

$$= \frac{1}{\frac{0.9379}{0.9400} + \frac{0.0496}{0.895} + \frac{0.00011}{1.3200} + \frac{0.00010}{2.48} + \frac{0.0094}{1.49} + \frac{0.0026}{1}} \times 62.43 \text{ lb/cuft}$$

$$= 58.7759 \text{ lb/cuft}$$

Rate Massa = 4215.870871 kg/jam

= 9294.3089 lb/jam

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

= $\frac{9294.3089 \text{ lb/jam}}{58.78 \text{ lb/cuft}}$

= 158.1314 cuft/jam

= 2.6355 cuft/menit

= 19.7150 gpm

Spesifikasi:

Berdasarkan Perry Ed8, Tabel 18-12, hal.18-121

Fungsi	=	Memisahkan kristal oleamida dari motherliquor	
Type	=	Nozzle Discharge Centrifuge	
Bowl Diameter	=	10	in
Speed	=	10000	rpm
Centrifuge Force	=	14200	lbf/ft^2
Power Motor	=	20	hp
Jumlah	=	1	buah

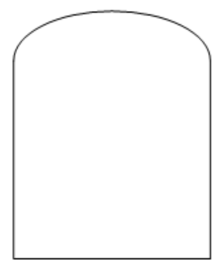
33. TANGKI PENAMPUNG-2 (F-351)

Fungsi = Menampung motherliquor dari centrifuge

Type = Silinder tegak, tutup bawah datar dan tutup atas torispherical

Dasar Pemillihan = Umum digunakan untuk liquid pada tekanan atmosfer

Kondisi Operasi = Tekanan operasi = 1 atm
Suhu operasi = 30 °C
Waktu tinggal = 3 hari



Komponen bahan masuk :

Komponen	Berat (kg/jam)	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO$	1.3581	0.0052	0.94
$C_{18}H_{34}O_2$	198.4778	0.7552	0.895
$CHCl_3$	37.9566	0.1444	1.49
H_2O	25.0064	0.0952	1
Total	**262.7989409**	**1**	

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62.43 \text{ lb/cuft}$$

$$= \frac{1}{\frac{0.005}{0.94} + \frac{0.755}{0.895} + \frac{0.14}{1.49} + \frac{0.095}{1}} \times 62.4 \text{ lb/cuft}$$

$$= 73.5035 \text{ lb/cuft}$$

Rate Massa = 262.7989 kg/jam
= 17374.2783 lb/jam

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

$$= \frac{17374.2783 \text{ lb/jam}}{73.50 \text{ lb/cuft}}$$

$$= 236.3736 \text{ cuft/jam}$$

Direncanakan penyimpanan untuk 7 hari, 2 buah tangki
sehingga volume bahan :

Volume bahan = Rate volumetrik x waktu tinggal

$$= \frac{236.3736 \times 24 \times 7}{2}$$

= 19855.3825 cuft

Asumsi bahan mengisi 80% volume tangki, maka :

$$\text{Volume tangki} = \frac{\text{Volume bahan}}{80\%}$$

$$= \frac{19855.3825}{80\%}$$

= 24819.2282 cuft

Menentukan dimensi tangki

Asumsi dimensi ratio H/D = 2 **(Ulrich T.4-27)**

H = 2 D

$$\text{Volume silinder} = \frac{\pi}{4} \times D^2 \times H$$

$= 0.785 \times D^2 \times 2\ D$

$= 1.57\ D^3$

Tutup atas menggunakan torispherical dished, sehingga :

V tutup atas = $0.000049\ D^3$ (Brownell; pers. 5.11, hal. 88)

jika diambil α = 30 °

Volume tangki = V silinder + V tutup atas

$24819.2282 = 1.57\ D^3 + 0.000049\ D^3$

$24819.2282 = 1.5700\ D^3$

D^3 =	15807.9322		H =	2 D	
D =	25.0972	ft	=	50.19437	ft
=	97.3314	in	=	194.66274	in
=	7.6496	m	=	15	m

Menentukan tinggi liquid dalam shell

$$\text{Volume liquid} = \frac{\pi}{4} \times D^2 \times H$$

$19,855.3825 = 0.785 \times 629.8687 \times H$

$19,855.3825 = 494.4469\ H$

H liq = 40.1568 ft

Menentukan Tekanan Design

P operasi = 1 atm = 14.7 psi

P hidrostatis = ρ x g/gc x H_L

$= 73.5035 \; \frac{lbm}{cuft} \times 1 \; \frac{lbf}{lbm} \times 40.1568 \; ft$

$= 2951.660206 \; \frac{lbf}{ft^2}$

= 20.4976 psi

P design = P operasi + P hidrostatis

= 14.7 + 20.4976

= 35.1976 psi

Untuk faktor keamanan, P design dipilih 10% lebih besar

P design = 1.1 x 35.1976

= 38.7174 psi

Menentukan Ketebalan Dinding Tangki

Tipe material penyusun tangki adalah Stainles Steel. Hal ini disebabkan :

- Mempunyai allowable stress yang besar
- Harga yang relatif lebih murah

Penentuan tebal shell :

$$t_{min} = \frac{P \; X \; ri}{f \; E \; - \; 0.6 \; P} + C$$

Dimana :

t_{min} = tebal shell minimum (in)

P = tekanan tangki (psi)

ri = jari-jari tangki (in; 1/2D) =

C = faktor korosi (in: 1/8D) **(Brownell, pg 254)**

E = faktor pengelasan (double welded; 0.8)

f = Stress allowable, bahan konstruksi *carbon steel SA-167 Grade 3*

Tipe 304, maka f all = 16,650 lb/in²

(Perry 7ed; T.28-11)

Asumsi tebal shell = 1 in

$$t_{min} = \frac{P \; x \; ri}{f \; E \; - \; 0.6 \; P} + C$$

$$1 = \frac{38.7174043 \; x \; 48.6657}{f \; x \; 0.8 \; - \; 0.6 \; x \; 38.72} + 1/8$$

$$7/8 = \frac{1884.2090}{0.8 \; f \; - \; 23.2304}$$

0.7 f - 20.327 = 1884.2090

0.70 f = 1904.5356

f = 2720.7652 psi

f hitung lebih kecil dari f *allowable* , jadi tebal shell 1 1/2 memenuhi

Menentukan Tebal Tutup Atas dan Bawah

Tutup atas dan bawah dipilih torispherical

OD = ID + 2 ts

= 97.331 + 2 (1)

= 99 in

Berdasarkan **Tabel 5.7 Brownell** didapatkan :

ts = 1 1/2

icr = 6 1/8 in

rc = 90 in

$$\frac{icr}{rc} = 6.8\%$$

karena icr > 6% rc, maka digunakan persamaan 7.76 dan 7.77

Tebal Standart Toripherical Dished (atas)

$$th = \frac{P \times rc \times W}{2\ f\ E - 0{,}2\ P} + C$$

Dimana:

th = tebal head (in)

W = faktor intensifikasi stress

f = Stress allowable, bahan konstruksi *carbon steel SA-167 Grade 3*

Tipe 304, maka f all = 16,650 lb/in² **(Perry 7ed; T.28-11)**

C = faktor korosi (in) = 1/8 , 10 tahun

(Tabel 6. Timmerhaus, hal.542)

E = faktor pengelasan digunakan double welded E = 0.8

(Tabel 5-7, Brownell, hal.254)

P = tekanan desain

Faktor Intensifikasi stress (W)

$$W = \frac{1}{4} \times \left(3 + \sqrt{\frac{rc}{icr}}\right)$$

$$= \frac{1}{4} \times 3 + \sqrt{\frac{170}{13}}$$

= 1.7083 in

Sehingga tebal tutup atas :

Asumsi tebal head = 1 7/8

$$th = \frac{P \times rc \times W}{2\ f\ E - 0{,}2\ P} + C$$

$$1\ 7/8 = \frac{38.7174 \times 90 \times 1.7083}{2 \times f \times 0.8 - 0.2 \times 38.7174} + 1/8$$

$$1.75 = \frac{5952.7365}{1.6\ f - 7.7435}$$

$$2.8\ f - 14 = 5952.7365$$

$$f = 2130.817$$

f hitung lebih kecil dari f *allowable* , jadi tebal tutup atas 5/16 memenuhi

Digunakan tebal head standart = 1 7/8 in

Tebal botton = tebal head = 1 7/8 in

untuk th = 1 7/8 in, maka sf = 1,5 - 4,5

(Tabel 5.6. Brownell, hal.88)

Diambil sf = 2

Menghitung tinggi tutup atas (OA)

$$BC = rc - icr$$
$$= 90 - 6.13$$
$$= 83.9 \text{ in}$$

$$AB = \frac{1}{2} Di - icr$$
$$= \frac{1}{2} \times 97.331 - 6.125$$
$$= 42.5407 \text{ in}$$

$$b = rc - (BC^2 - AB^2)^{0,5}$$
$$= 90 - (7035 - 1810)^{0,5}$$
$$= 17.7 \text{ in}$$

Jadi, tinggi tutup adalah

$$OA = b + sf + t$$
$$= 17.7 + 2 + 1\ 7/8$$
$$= 21.5887 \text{ in}$$
$$= 1.7991 \text{ ft}$$

untuk tebal tutup bawah datar karena tutup menumpang diatas semen, maka

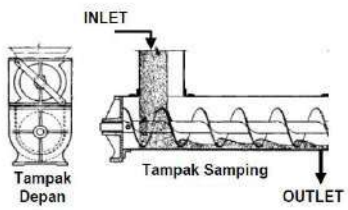
tebal tutup = 1/4 in (Brownell & Young; 58)

Spesifikasi :

Fungsi	=	Menampung motherliquor dari centrifuge
Type	=	Tangki berbentuk silinder tegak dengan tutup atas berbentuk Torispherical Head dan tutup bawah plate datar
Volume	=	24819.2282 cuft
Diameter shell	=	25.0972 ft
Tinggi shell	=	50.19437 ft
Tinggi tutup atas	=	1.80 ft
Tebal shell	=	1 in
Tebal tutup atas	=	1 7/8 in
Tebal tutup bawah	=	1/4 in
Bahan konstruksi	=	*Carbon steel SA-167 Grade 3*
Jumlah	=	2 buah

34. SCREW CONVEYOR-3 (J-352)

Fungsi = Memindahkan bahan dari centrifuge ke rotary dryer
Type = Plain spouts or chutes
Dasar Pemilihan = Umum digunakan untuk padatan dengan sistem tertutup



Feed masuk screw conveyor

Komponen	Massa (kg/jam)	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO_{(l)}$	1.4296	0.0003	0.94
$C_{18}H_{35}NO_{(s)}$	3954.0499	0.9344	0.94
$C_{18}H_{34}O_{2(l)}$	208.9240	0.0494	0.895
$CO(NH_2)_{2(s)}$	0.4490	0.000106	1.32
$AlCl_{3(s)}$	0.4221	0.000100	2.48
$CHCl_{3(l)}$	39.9543	0.0094	1.49
$H_2O_{(l)}$	26.3226	0.0062	1
Total	**4231.5514**	**1**	**9.065**

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62.43 \text{ lb/cuft}$$

$$= \frac{1}{\frac{0.0003}{0.9400} + \frac{0.9344}{0.895} + \frac{0.0494}{1.3200} + \frac{0.00011}{1.32} + \frac{0.00010}{2.48} + \frac{0.0094}{1.49} + \frac{0.006}{1}} \times 62.43 \text{ lb/cuft}$$

$$= 57.0404 \text{ lb/cuft}$$

Rate Massa = 4231.551416 kg/jam
= 9328.8783 lb/jam

$$\text{Rate Volumetrik} = \frac{\text{Rate massa}}{\text{Densitas}}$$

$$= \frac{9328.8783}{57.0404}$$

= 163.55 cuft/jam

= 2.7258 cuft/menit

= 20.3904 gpm

$$\text{Power Motor} = \frac{C \times L \times W \times F}{33000}$$

Keterangan : C = Kapasitas (cuft/menit)

L = Panjang (ft)

W = Densitas bahan (lb/cuft)

F = Faktor bahan

Dari **Badger; Hal.627**, didapatkan F = 4

Asumsi Panjang Conveyor L = 30 ft

$$\text{Power Motor} = \frac{2.7258 \times 30 \times 57.0404 \times 4}{33000}$$

= 0.5654 hP

Untuk power hp<2, maka dikalikan 2 **(Badger :713)**

Power Motor = 0.5654 x 2

= 1.1308 hp

Efisiensi Motor = 80% maka,

$$\text{Power Motor} = \frac{1.1308}{80\%}$$

= 1.4135 = 1 hP

Dari **Perry 7ed, Tabel 21-6 hal.21-8**, berdasarkan kapasitas didapatkan :

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

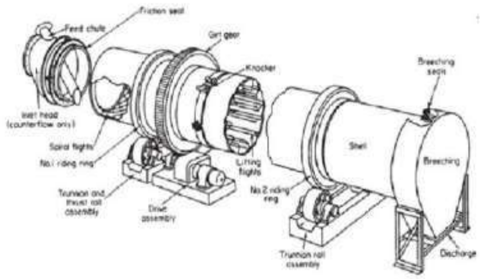
Spesifikasi :

Fungsi	=	Memindahkan bahan dari centrifuge ke rotary dryer
Type	=	Plain spouts or chutes
Dasar pemilihan	=	Umum digunakan untuk padatan dengan sistem tertutup
Kapasitas	=	4231.551 kg/jam
Rate volumetrik	=	20.3904 gpm
Diameter flight	=	9 in
Diameter pipa	=	2 1/2 in
Diameter of shaft	=	2 in
Kecepatan (rpm)	=	40
Elevasi	=	Horizontal
Panjang	=	30 ft
Efisiensi	=	80%
Power	=	1 hP
Jumlah	=	1 buah

35. Rotary Dryer (B-360)

Fungsi : Mengeringkan kristal oleamida

Tipe : Single Shell Direct Heat Rotary Dryer



Data Komponen

Komponen	Berat Kg/Jam	Fraksi	ρ (gr/ml)	Fraksi/ρ
$C_{18}H_{35}NO_{(l)}$	0.0715	0.0000	0.9400	0.0000
$C_{18}H_{35}NO_{(s)}$	3954.0499	0.9963	0.9400	1.0599
$C_{18}H_{34}O_{2(l)}$	10.4462	0.0026	0.8950	0.0029
$CO(NH_2)_{2(s)}$	0.4490	0.0001	1.3200	0.0001
$AlCl_{3(s)}$	0.4221	0.0001	2.4800	0.0000
$CHCl_{3(l)}$	1.9977	0.0005	1.4900	0.0003
$H_2O_{(l)}$	1.3161	0.0003	1.0000	0.0003
Total	**3968.7525**	**1**		**1.0636**

Rate Bahan Masuk = 3968.75248 Kg/Jam
= 8731.25545 lb/jam

Total Panas (Q) = 16646.2443 Kkal/Jam
= 65919.1274 Btu/jam

Suhu Bahan				Suhu Udara			
T in	=	30	°C	t in	=	35.00	°C
	=	86	°F		=	95	°F
T out	=	70	°C	t out	=	68.8	°C
	=	158	°F		=	156	°F

a. Perhitungan ΔT LMTD

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

Δt_2 = 69.8 °F
Δt_1 = 63 °F
ΔT LMTD = 66.346 °F
= 292.231 K

b. Perhitungan Area Of Drum
Asumsi
Solid Velocity (us) = 0.60 m/s **(Ulrich ; Tabel 4-10)**
Luas Aliran Solid (As) = $\dfrac{ms}{\rho s \times us}$

Keterangan :
As = Area drum yang dilewati solid (m²)
ms = Rate massa (Kg/s)
= 1.102 Kg/s
ρs = Densitas padatan (Kg/m³)
= 1.21 Kg/m³
us = Kecepatan padatan (m/s)
= 0.6 m/s

As = 1.518500335 m²

$$As = \frac{\pi}{4} \times S$$

$$1.51850033 = \frac{\pi}{4} \times D^2$$

D = 1.39 m = 4.5630755 ft

c. Perhitungan Koefisien Volumetrik Heat Transfer, Ua

$$Ua = \frac{240 \times G^{0,67}}{D}$$ **(Ulrich ; Tabel 4-10)**

Keterangan :
Ua : Koefisien volumetrik heat transfer (J/m³ s K)
G : Average mass flux (Kg/s m²)
: 0,5 - 5
: 0.5
D : Diameter (m)
: 1.39 m

Ua = 108.454737 J/m² s K

d. Perhitungan Panjang Rotary Dryer

$Q = Ua \times V \times \Delta T$ **(perry ed 7 hal 12-**

Keterangan :

Q	:	Panas total	(J/s)
	:	19346.64 J/s	
Ua	:	Koefisien volumetrik heat transfer	(J/m³ s K)
		108.4547 J/m² s K	
V	:	Volume	(m³)
ΔT	:	Logmean temperature difference	(K)
		292.23 K	

V = 0.61042203 m³

V = As x L

L = 0.402 m

L/D = 0.28903 (memenuhi **(Ulrich ; Tabel 4-10 :ratio L/D = 4 - 6)**

e. Perhitungan Time Passes

$$\theta = \frac{0.23\ L}{S\ N^{0,9}\ D} \pm 0.6\ \frac{B\ L\ G}{F}$$ **(Perry 7th ed.,hal 12-55)**

$B = 5\ Dp^{-0,5}$

θ = Time of passes ; menit

L = Panjang drum ; m

S = Slope drum ; cm/m

N = Speed ; rpm (1–7 rpm) **[Perry 7ed, hal. 12-68]**

D = Diameter drum ; m

B = Konstanta material

G = Rate massa udara ; kg/m^2.s

F = Rate solid ; kg solid/m2.jam

Dp = Berat partikel ; μm **[Perry 6ed, T.21-6]**

S = 0 - 8 cm/m **[Perry 7ed, hal. 12-56]**

Asumsi :

Dp = 10 mesh

= 1680 μm

S = 0.01 cm/m

N = 6 rpm

G = 0.5 kg/m^2.s **[Perry 7ed, hal. 12-55]**

A = 1.519 m²

$$F = \frac{\text{Rate massa}}{A}$$

= 6.87929 Kg/m² Jam

B = 0.12199
θ = 1.3275 menit
= 79.65 detik

f. Sudut Kemiringan

Slope = 0.01 cm/m

Slope actual = 0.01 cm/m x 0.402 m

= 0.004 cm

α = 0.23044 °

g. Flight Rotary Dryer

Tinggi Flight = 1/12D - 1/8D **(Perry 7ed, 12-56)**

Jumlah Flight = 2,4 - 3 D **(Perry 7ed, 12-54)**

Panjang Flight = 0,6 - D

maka

Tinggi Flight = 1/3 D
= 1/2 m

Jumlah Flight = 2.5 D
= 11.41 buah = 19 buah

Panjang Flight = 0.8 D
= 1.1 m

Total Circle = $\frac{\text{Panjang Drum}}{\text{Panjang Flight}}$
= 0.36

Total Jumlah Flight = Total Circle x Jumlah Flight
= 6.86
= 162.00

h. Tebal Shell Drum

$$\rho \text{ mix} = \frac{1}{\Sigma \dfrac{\text{Fraksi Berat Komponen}}{\rho \text{ komponen}}} \times 62.43 \; \frac{lb/ft^3}{g/cm^3}$$

$= 58.6943 \; lb/ft^3$

P design (P_H)

$$P_B = \frac{r \cdot \rho_B \cdot (g/gc)}{2 \cdot \mu \cdot k} \times [\ 1 - e^{-2\mu k\ ZT/r}\ ]$$

(Mc.Cabe, pers. 26-24)

P_B = Tekanan vertikal dasar bejana ; lb/ft^2
ρ_B = Bulk density bahan ; lb/ft^3
μ' = Koefisien gesek = 0,35 - 0,55 = 0.55
ri = Jari - jari tangki ; ft
k' = Ratio tekanan normal = 0,35 - 0,6 **(Mc. Cabe, pers 26-17)**
Z_T = Tinggi total material dalam tangki ; ft

$$k' = \frac{1 - \sin \alpha}{1 + \sin \alpha}$$ **(Mc.Cabe, pers. 26-24)**

α = 30
k' = 0.33 (memenuhi range)

Z_T = Tinggi total material 15% tinggi drum
= 0.06 m **(Ulrich,T.4-10)**
= 0.20 ft
= 2.4 in
ri = 0.70 m
= 2.28 ft
= 27.4 in

$$P_B = \frac{r \cdot \rho_B \cdot (g/gc)}{2 \cdot \mu \cdot k} \times [\ 1 - e^{-2\mu k\ ZT/r}\ ]$$

= 11.34 lbf/ft^2
= 0.079 Psi

Tekanan lateral = k' x P_B
P_L = 0.026249 Psi
P operasi = $P_B + P_L$
= 0.105 Psi

P design dibuat 10% lebih besar untuk faktor keamanan
P design = 0.1155 psi

$$t_h = \frac{P \times ri}{fE - 0{,}6P} + C$$

dimana :

t_s	=	tebal shell	in
P	=	tekanan design	psi
	=	0.1155 psi	
ri	=	jari - jari dalam	in
	=	27.3798 in	
f	=	stress maximum	psi (tabel 13.1; brownell & young
		digunakan bahan SA 283 C carbon steel	
	=	12650 psi	
E	=	faktor pengelasan	
	=	0.8	
C	=	faktor korosi	
	=	1/8	

t_h = 1/8 in ; 2.005 / 16

maka dipilih tebal shell sebesar = 1/5 in

i. Isolasi

Tebal batu isolasi	=	1 - 10	cm
	=	10	cm
	=	4	in
	=	0.333	ft
ID rotary dryer	=	1.3908	m
	=	4.563	ft
Tebal shell	=	1/5	in
	=	0.02	ft
OD rotary dryer	=	4.595	ft
Diameter rotary + isolasi	=	5.261	ft

j. Power Rotary Dryer

Rate massa	=	8731.25545	lb/jam
Solid hold up	=	15%	
Berat Bahan	=	1309.68832	lb/Jam

Berat Shell

We = $1/4 \times \pi \times (Do^2 - Di^2) \times L \times \rho steel$

= 0.785 x 0.2862 x 1.31893 x 490

= 145.188 lb

Berat Isolasi

Wi = $1/4 \times \pi \times (Do^2 - Di^2) \times L \times \rho$ isolasi
= 0.785 x 7 x 1.31893 x 19
= 129.2539 lb

Berat lain - lain = 158.413 lb

Berat Total = 1742.543 lb

$$\text{power} = \frac{N \times (4{,}75\ d\ w + 0{,}1925\ D\ W + 0{,}33\ W)}{100000}$$

(Perry 7ed, 12-60)

N = Putaran rotary ; rpm
d = Diameter shell ; ft
w = Berat bahan ; lb
D = Diameter shell x 2 ; ft
W = Berat total ; lb

N = 6 rpm
d = 4.563 ft
w = 1309.69 lb
D = 9.1266 ft
W = 1742.54 lb

$$\text{power} = \frac{N \times (4{,}75\ dw + 0{,}1925\ DW + 0{,}33W)}{100000}$$

$$\text{power} = \frac{6 \times (28388.4 + 3061.42 + 575.039}{100000}$$

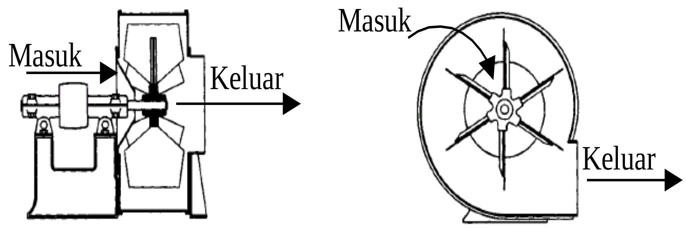
= 1.921489673 hp

SPESIFIKASI ROTARY DRYER (B-270)

Fungsi	=	Mengeringkan kristal oleamida				
Kapasitas	=	3968.752	kg/jam			
Diameter	=	4.563	ft	=	1.391	m
Panjang	=	1.318929	ft	=	0.402	m
Tebal isolasi	=	4	in	=	10.16	cm
Tebal shell	=	1/5	in	=	1/2	cm
Sudut Rotary	=	0.230	^{o}			
Jumlah flight	=	162	buah			
Time of passes	=	1.3275	menit			
power	=	1.92149	hp			

36. BLOWER (G-361)

Fungsi	:	Untuk menghembuskan udara luar menuju rotary dryer sebagai pemanas
Type	:	Centrifugal blower
Dasar Pemilihan	:	Sesuai dengan jenis bahan dan effisiensi tinggi



Rate massa udara = 3,319.1705 kg/jam
= 7,317.4433 lb/jam

$$\rho \text{ campuran} = \frac{492}{T} \times \frac{P}{1 \text{ atm}} \times \frac{BM}{359}$$ **(Himmelblau; 249)**

Keterangan :

T	=	Suhu bahan (°R)	=	30	°C	=	546 °R
P	=	Tekanan bahan (atm)	=	1 atm			
BM	=	Berat molekul campuran	=	28.8			
492	=	Suhu udara standar (0°C = 492 °R)					
359	=	BM udara standar					

$$\rho \text{ campuran} = \frac{492}{T} \times \frac{P}{1 \text{ atm}} \times \frac{BM}{359}$$

$$= \frac{492}{546} \times \frac{1}{1 \text{ atm}} \times \frac{28.84}{359}$$

$$= 0.0724 \text{ lb/cuft}$$

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

$$= \frac{7{,}317.4433 \text{ lb/jam}}{0.0724 \text{ lb/cuft}}$$

$$= 101{,}084.8559 \text{ cuft/jam}$$

$$= 1{,}684.7476 \text{ cuft/mnt}$$

<u>Menentukan dimensi blower</u>

Asumsi : Aliran turbulen

Dipilih pipa 12 in, sch 40

OD = 12.8 in

ID = 11.9 in

A = 15.8 in²

Perhitungan power blower

hP = 0.00016 x Q x ΔP **(Perry ed 7 : 10-46)**

Pressure drop diambil = 0.5 psi

Dimana:

1 psi = 27.7 in H_2O

0.5 psi = 13.9 in H_2O

hP = 0.00016 x Q x ΔP

= 0.00016 x 1,684.7476 x 13.9

= 3.6634 hP

$$\text{Effisiensi} = \frac{\text{hP blower}}{\text{hP shaft}}$$ **(Perry ed 7 ; pers. 10-89 ; pg. 10-46)**

Effisiensi blower = 40% - 80%

Dipilih = 80%

$$\text{hP shaft} = \frac{3.6634}{80\%}$$

= 4.5792 hP

Spesifikasi :

Fungsi	:	Untuk menghembuskan udara luar menuju rotary dryer sebagai pemanas
Type	:	Centrifugal blower
Dasar Pemilihan	:	Sesuai dengan jenis bahan dan effisiensi tinggi
Rate Volumetrik	:	1,684.7476 cuft/min
Effisiensi blower	:	80%
Power	:	5 hP
Bahan konstruksi	:	Carbon steel
Jumlah	:	1 buah

37. MOLECULAR SIEVE (D-362)

Fungsi : Mengurangi kelembaban udara yang akan masuk ke Heater

Perhitungan

Feed udara yang masuk = 3319.170491 kg/jam
Relative humidity = 90% **(BMKG Kota Karawang)**
T udara masuk = 30 ^oC
Humidity = 0.024774 kg H_2O/kg dry air **(Psychrometric Chart)**
Kandungan air per jam = 0.024774 x 3319.17049
= 82.2291297 kg/jam
Kapasitas serap MS 4A = 80.0%
Bulk Density MS 4A = 650 kg/m^3 **(Sorbchemindia.com)**
H_2O tertahan dalam 1 hari = 82.2291297 x 24 jam
= 1973.49911 kg/hari

Kebutuhan MS 4A

$$\frac{1}{x}\ \text{kg} = \frac{80.0\%}{1973.499114}$$

Jadi, kebutuhan MS 4A = 2466.873892 kg/hari
Bila proses regenerasi dilakukan 8 jam sekali, maka MS 4A 3x sehari:
Kebutuhan MS 4A untuk regenera = 822.291297 kg

$$\text{Volume MS 4A} = \frac{\text{Kebutuhan MS}}{\text{Bulk density}} = \frac{822.2912974\ \text{kg}}{650\ \text{kg/m}^3} = 1.265063535\ \text{m}^3$$

Volume tangki = 2 x Volume molecular sieve
= 2 x 1.265063535
= 2.530127069 m^3

Perhitungan dimensi :
Asumsi : H = 2D

$$V\ \text{tangki} = \frac{\pi}{4} \times D^2 \times H$$

$$2.5301 = 0.785 \times D^2 \times 2D$$
$$2D^3 = 3.2231$$
$$D^3 = 1.6115$$
$$D = 1.1724 \text{ m} = 3.8465 \text{ ft}$$
$$H = 2.3448 \text{ m} = 7.6930 \text{ ft}$$

$$\text{Tinggi MS 4A} = \frac{\text{Volume MS}}{\text{Luas tangki}}$$
$$= \frac{1.2651}{\frac{\pi}{4} \times D^2}$$
$$= \frac{1.2651}{0.7850 \times 1.3746}$$
$$= 1.172413724 \text{ m}$$
$$= 3.846501842 \text{ ft}$$

Spesifikasi :

Fungsi	=	Mengurangi kelembaban udara yang masuk ke heater						
Kapasitas	=	822.2912974 kg/7 hari						
Dimensi	=	Diameter tangki	=	1.1724	m =	3.8465	ft	
		Tinggi tangki	=	2.3448	m =	7.6930	ft	
		Tinggi MS 4A	=	1.1724	m =	3.8465	ft	
Bahan resin	=	4A						
Bahan konstruks	=	Carbon steel SA-283 grade C						
Jumlah	=	1 buah						

37. MOLECULAR SIEVE (D-362)

Fungsi : Mengurangi kelembaban udara yang akan masuk ke Heater

Perhitungan

Feed udara yang masuk = 3319.170491 kg/jam

Relative humidity = 90% **(BMKG Kota Karawang)**

T udara masuk = 30 ^oC

Humidity = 0.024774 kg H_2O/kg dry air **(Psychrometric Chart)**

Kandungan air per jam = 0.024774 x 3319.17049

= 82.2291297 kg/jam

Kapasitas serap MS 4A = 80.0%

Bulk Density MS 4A = 650 kg/m^3 **(Sorbchemindia.com)**

H_2O tertahan dalam 1 hari = 82.2291297 x 24 jam

= 1973.49911 kg/hari

Kebutuhan MS 4A

$$\frac{1}{x}\ \text{kg} = \frac{80.0\%}{1973.499114}$$

Jadi, kebutuhan MS 4A = 2466.873892 kg/hari

Bila proses regenerasi dilakukan 8 jam sekali, maka MS 4A 3x sehari:

Kebutuhan MS 4A untuk regenera = 822.291297 kg

$$\text{Volume MS 4A} = \frac{\text{Kebutuhan MS}}{\text{Bulk density}}$$

$$= \frac{822.2912974\ \text{kg}}{650\ \text{kg/m}^3}$$

$$= 1.265063535\ \text{m}^3$$

Volume tangki = 2 x Volume molecular sieve

= 2 x 1.265063535

= 2.530127069 m^3

Perhitungan dimensi :

Asumsi : H = 2D

$$V\ \text{tangki} = \frac{\pi}{4} \times D^2 \times H$$

$$2.5301 = 0.785 \times D^2 \times 2D$$
$$2D^3 = 3.2231$$
$$D^3 = 1.6115$$
$$D = 1.1724 \text{ m} = 3.8465 \text{ ft}$$
$$H = 2.3448 \text{ m} = 7.6930 \text{ ft}$$

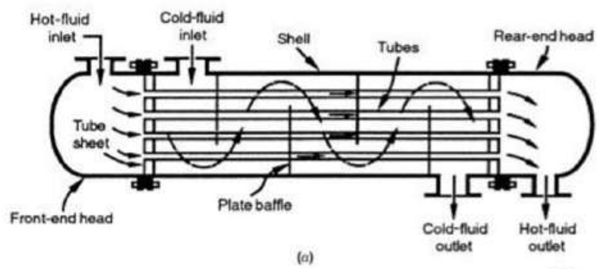
$$\text{Tinggi MS 4A} = \frac{\text{Volume MS}}{\text{Luas tangki}} = \frac{1.2651}{\frac{\pi}{4} \times D^2} = \frac{1.2651}{0.7850 \times 1.3746} = 1.172413724 \text{ m} = 3.846501842 \text{ ft}$$

Spesifikasi :

Fungsi	=	Mengurangi kelembaban udara yang masuk ke heater
Kapasitas	=	822.2912974 kg/7 hari
Dimensi	=	Diameter tangki = 1.1724 m = 3.8465 ft
		Tinggi tangki = 2.3448 m = 7.6930 ft
		Tinggi MS 4A = 1.1724 m = 3.8465 ft
Bahan resin	=	4A
Bahan konstruks	=	Carbon steel SA-283 grade C
Jumlah	=	1 buah

38. HEATER (E-363)

Fungsi : Memanaskan udara menuju rotary dryer
Type : Shell and tube, 1-2 exchanger (Fixed tube)
Kondisi operasi : Tekanan = 1 atm
Suhu = 120 °C



1. Neraca Panas :

Dari neraca massa dan neraca panas diperoleh:

Berat bahan	=	3236.94136	kg/jam
	=	7136.16093	lb/jam
Panas yang dibutuhkan, Q	=	60483.6188	kkal/jam
	=	239857.881	Btu/jam
Steam yang digunakan, W_{steam}	=	119.397717	kg/jam
	=	263.224207	lb/jam
W_{fluida} dingin	=	671.00	kg/jam
	=	1479.2866	lb/jam

2. Penentuan ΔT_{LMTD}

Hot fluid (°F)		Cold fluid (°F)	Δt
298.4	Higher temp	248	50
296.6	Lower temp	86	211

$$\Delta T_{LMTD} = \frac{\Delta t_2 - \Delta t_1}{2.3 \log \frac{\Delta t_2}{\Delta t_1}}$$ **(Kern; Pers. 5.14)**

$$= \frac{50 - 211}{2.3 \log \frac{50}{211}}$$

$$= \frac{-160}{-1.428}$$

$$= 112.156 \ \text{°F}$$

$$R = \frac{T1 - T2}{t2 - t1} = \frac{298 - 297}{248 - 86} = 0.011$$

$$S = \frac{t2 - t1}{T1 - t1} = \frac{248 - 86}{298.4 - 86} = 0.7627$$

F_T = 0.980 **(Kern; Fig. 18)**

Δt = LMTD x F_T (Untuk 1 dan 2 shell and tube)
= 112.156 x 0.980
= 109.913 °F

3. Tc dan tc dipakai temperatur rata-rata

Tc = Tav steam

$$Tc = \frac{T_1 + T_2}{2} = \frac{298.4 + 296.6}{2} = 297.5 \text{ °F}$$

tc = tcav bahan

$$tc = \frac{t_1 + t_2}{2} = \frac{86 + 248}{2} = 167 \text{ °F}$$

(μ = 0.014) steam **(Kern; Fig. 15)**
(μ = 0.025) udara
Dipilih tipe : 1 - 2 Heat Exchanger
Digunakan shell and tube dengan ukuran :
OD, BWG = 3/4 in 16 BWG
Pitch = 1 in Square Pitch
Panjang Tube, L = 12 ft

Berdasarkan Kern: T.10, hal.843

ID = 0.62 in
a't = 0.302 in^2
a" = 0.1623 ft^2/ft panjang
Hot fluid : Steam
Cold fluid : Udara kering

Nilai U_D range = 5-50 Btu/jam.ft^2°F (Cold fluid = Light organics)
(Kern T.8, hal.840)

Dipilih U_D = 5 Btu/jam.ft^2°F

$$A = \frac{Q}{\Delta T_{LMTD} \times U_D}$$

$$= \frac{239857.8807}{109.913 \times 5}$$

$$= 436.4498 \text{ ft}^2$$

Jumlah Tube (Nt) $= \dfrac{A}{L \times a''}$

$= \dfrac{436 \text{ ft}^2}{12 \times 0.1623 \text{ ft}}$

= 224.0962 buah

Asumsi 2 tube passes, dari Kern; tabel 9 diperoleh

Digunakan Nt =

ID Shell = 35 in

Phases = 2

Koreksi U_D :

A = Nt x L x a"

= 224 x 12 x 0.1623

= 436.4498 ft²

$UD = \dfrac{Q}{A \times \Delta t}$

$= \dfrac{239{,}858}{436.450 \times 109.913}$

= 5 Btu/j ft²°F

Fluida panas (Tube side)	Fluida dingin (shell side)
4) a't = 0.302 in²	4') $B = \dfrac{ID}{5} = \dfrac{35}{5} = 7$ in
$at = \dfrac{Nt \times a't}{144 \; n}$	as = ID x C'B / 144 P_T
$= \dfrac{224.1 \times 0.302}{144 \times 2}$	$= \dfrac{35 \times 0.25 \times 7}{144 \times 2}$
= 0.2350 ft²	= 0.2127 ft²
5) $Gt = \dfrac{W}{at}$	5') $Gs = \dfrac{W}{as}$
$= \dfrac{263.2242066}{0.2350}$	$= \dfrac{1{,}479}{0.2127}$
= 1120.151686 lb/jam.ft²	= 6,956 lb/jam.ft²
6) Pada Tc = 297.5 °F	6') Pada tc = 167 °F
μ = 0.014 x 2.42	μ = 0.025 x 2.42
= 0.0339 lb/ft.jam	= 0.0605 lb/ft.jam
D = 0.62 in	untuk 3/4 in OD, 1-in square
= 0.0517 ft	pitch **(Kern, Fig.28)**
$Re.t = \dfrac{DGt}{\mu}$	De = 0.95 in
	= 0.0792 ft
$= \dfrac{0.05167 \times 1120.151686}{0.0339}$	$Re.s = \dfrac{De \times Gs}{\mu}$
= 1,708.220	

	$= \dfrac{0.0792 \times 6{,}956}{0.0605}$
	$=$ 9,101.7668
	7') Dari fig. 24 didapat
	jH = 500
	8') tc = 167 °F
	k = 0.0156 Btu/(hr)(ft^2)(^{o}F/ft)
	(Tabel 5)
	$= (c \times \mu/k)^{1/3}$
	$= \left\lvert \dfrac{1 \times 0.0605}{0.0156} \right\rvert^{(1/3)}$
	= 1.5445
	μw = 1 (standart)
	$\varphi s = (\mu/\mu w)^{0,14}$
	= 0.6752
9) Hio untuk kondensasi steam	9') ho = $J_H \times (k/De) \times (c \times \mu / k)^{1/3} \times \varphi s$
Hio = 1500 Btu/j ft² °F	= 102.7502 Btu/j ft² °F
(Kern;168)	

10) Clean overall coefficient (Uc)

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

$$= \frac{1500 \times 102.7502}{1500 + 102.7502}$$

$= 96.163$ Btu/j ft² °F

11) Design overall coefficient (Ud)

$$Ud = Q / (A \times \Delta t\ LMTD)$$

$$= \frac{239{,}858}{436.4498 \times 112.156}$$

$= 5$ Btu/j ft² °F

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

$$= \frac{96.163 - 5}{96.163 \times 5}$$

$= 0.1937$ j ft^2 F/BTU

Rd perhitungan > Rd data (Kern ; T 12)

0.1937 > 0.002

maka dari segi faktor kekotoran memenuhi syarat

Pressure drop

Steam (Tube side)	Air (Shell side)
1) Re.t = 1708.2203 f = 0.00035 (Kern, Fig.26) v = 6.466 Interpolasi (Kern, Tabel.7) s = 0.0025	1') Re.s = 9,102 f = 0.0013 (Kern, Fig.29) s = 1.0800 2') N+1 = 12 L / B = 20.5714 Ds = 35 / 12 = 2.9167 ft
2) $\Delta Pt = \dfrac{f.Gt^2.L.n}{5{,}22 \times 10^{10}.Ds.\phi t}$ = 3.64901E-05 psi	3') $\Delta Ps = \dfrac{f.Gs^2.Ds.(N+1)}{5{,}22 \times 10^{10}.De.s.\phi t}$ = 0.00125225 psi

Spesifikasi :

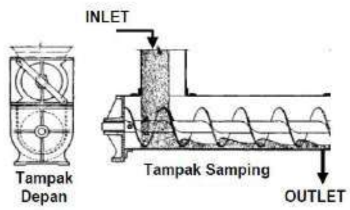
Fungsi	=	Memanaskan udara menuju rotary dryer
Type	=	Shell and tube, 1-2 exchanger (Fixed tube)
Shell side		
ID	=	35 in
B	=	7 in
n	=	2 Passes
Tube side		
Nt	=	224 buah
L	=	12 ft
OD	=	3/4 in
BWG	=	16 BWG
n	=	1
Pitch	=	Square pitch 1"
Heat exch, area A	=	436.4498 ft^2
Jumlah heat exchanger	=	1
Bahan konstruksi	=	Carbon Steel

39. COOLING SCREW CONVEYOR (J-364)

Fungsi = Mendinginkan kristal Oleamida dari rotary dryer ke bucket elevator hingga 30°C

Type = Plain spouts or chutes

Dasar Pemilihan = Umum digunakan untuk padatan dengan sistem tertutup



Feed masuk screw conveyor

Komponen	Massa (kg/jam)	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO_{(l)}$	0.071478909	0.0000	0.94
$C_{18}H_{35}NO_{(s)}$	3914.509375	0.9971	0.94
$C_{18}H_{34}O_{2(l)}$	10.44619971	0.0027	0.895
$CO(NH_2)_{2(s)}$	0.444519137	0.0001	1.32
$AlCl_{3(s)}$	0.417847989	0.0001	2.48
$CHCl_{3(l)}$	0.099885845	0.0000	1.49
$H_2O_{(l)}$	0.065806384	0.0000	1
Total	**3926.055113**	**1**	**9.065**

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62.43 \text{ lb/cuft}$$

$$= \frac{1}{\frac{1.82E-05}{0.9400} + \frac{0.9971}{0.94} + \frac{0.0027}{0.8950} + \frac{0.00011}{1.32} + \frac{0.00011}{2.48} + \frac{2.54E-05}{1.49} + \frac{2E-05}{1}} \times 62.43 \text{ lb/cuft}$$

$$= 58.6828 \text{ lb/cuft}$$

Rate Massa = 3926.055113 kg/jam

= 8655.3811 lb/jam

Rate Volumetrik $= \dfrac{\text{Rate massa}}{\text{Densitas}}$

$= \dfrac{8655.3811}{58.6828}$

= 147.49 cuft/jam

= 2.4582 cuft/menit

= 18.3889 gpm

Power Motor = $\dfrac{C \times L \times W \times F}{33000}$

Keterangan : C = Kapasitas (cuft/menit)
L = Panjang (ft)
W = Densitas bahan (lb/cuft)
F = Faktor bahan
Dari **Badger; Hal.627**, didapatkan F = 4

Asumsi Panjang Conveyor L = 30 ft

Power Motor $= \dfrac{2.4582 \times 30 \times 58.6828 \times 4}{33000}$

= 0.5246 hP

Untuk power hp<2, maka dikalikan 2 **(Badger :713)**

Power Motor = 0.5246 x 2

= 1.0491 hp

Efisiensi Motor = 80% maka,

Power Motor $= \dfrac{1.0491}{80\%}$

= 1.3114 = 1 hP

Dari **Perry 7ed, Tabel 21-6 hal.21-8**, berdasarkan kapasitas didapatkan :

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 :

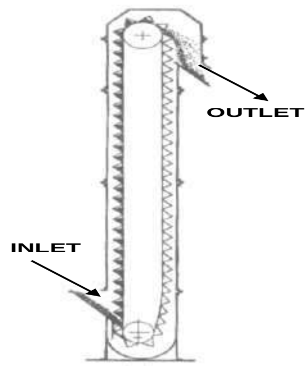
Fungsi	=	Mendinginkan bahan sampai dengan 30°C
Type	=	Plain spouts or chutes
Dasar pemilihan	=	Umum digunakan untuk padatan dengan sistem tertutup
Kapasitas	=	3926.055 kg/jam
Rate volumetrik	=	18.3889 gpm
Diameter flight	=	9 in
Diameter pipa	=	2 1/2 in
Diameter of shaft	=	2 in
Kecepatan (rpm)	=	40
Elevasi	=	Horizontal
Panjang	=	30 ft
Efisiensi	=	80%
Power	=	1 hP
Jumlah	=	1 buah

40. BUCKET ELEVATOR-3 (J-365)

Fungsi : Memindahakan oleamida dari screw cooling conveyor menuju ball mill

Type : Centrifugal Discharge Bucket Elevator

Dasar Pemilihan : Untuk memindahkan bahan dengan ketinggian tertentu



Rate massa = 3943.5503 kg/jam

= 3.9436 ton/jam

Dari Perry 7ed, Tabel. 21-8, Dipilih *bucket elevator* dengan spesifikasi sebagai berikut:

Kapasitas maksimum = 14 ton/jam

Tinggi *bucket* = 25 ft

Perhitungan *power* :

Power pada *head shaft* = 1 hP

Power tambahan = 0.02 hP/ft

= 0.02 hP/ft x 25 ft

= 0.5 hP

Power total = 1 + 0.5

= 1.5 hP

Efisiensi motor = 80%

Powe r total $= \dfrac{1.5}{80\%}$

= 1.88 hP ≈ 2 hP

Spesifikasi :

Fungsi = Memindahakan oleamida dari screw cooling conveyor menuju ball mill

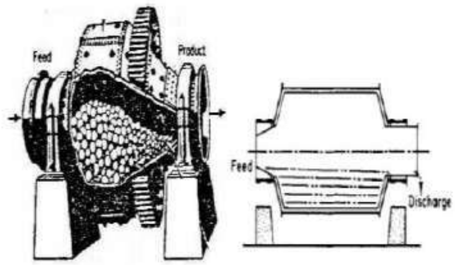
Type = Centrifugal Discharge Bucket Elevator

Kapasitas maksimum = 14 ton/jam

Ukuran bucket	=	6 in x 4 in x 4 1/4 in
Tinggi bucket	=	25 ft
Bucket spacing	=	12 in
Ukuran *feed* (max)	=	3/4 in
Bucket speed	=	225 ft/mnt
Putaran *head shaft*	=	43 rpm
Lebar *belt*	=	7 in
Power total	=	2 hP
Bahan	=	*Carbon Steel*
Jumlah	=	1 buah

41. BALL MILL (C-370)

Fungsi = Menghaluskan kristal sampai ukuran 100 mesh
Type = Marcy ball mill
Dasar pemilihan = Sesuai dengan jenis bahan dan kapasitas



Perhitungan :

Rate bahan = 3926.055113 kg/jam
= 3.9261 ton/jam
= 94.2253 ton/hari

Untuk produk berukuran 100 nesh dengan kapasitas 94.2253 ton/hari
Dari **Perry 7^{ed}, tabel 20-16** didapat :

Jenis Ball Mill	=	Marcy Ball Mills
Power	=	135-150 hp
No.Sieve	=	100 mesh
Rate Maksimum	=	180 ton/hari
Berat Bola Baja	=	13.1 ton/hari
Ball Mill Speed	=	22.5 rpm
Panjang Mill	=	7 ft
Diameter Mill	=	5.0 ft
Tinggi Mill	=	5.0 ft

Untuk Marcy ball mill, maka digunakan 3 ukuran bola baja :
5 & 3.5 & 2.5 in **(Stanly Walas; Fig 12.5(d) hal 346)**
Asumsi berat bola baja didistribusikan sama rata menjadi 3 bagian (berdasarkan 3 ukuran)

Jadi, berat bola baja masing-masing ukuran $\frac{13.1}{3} = 4.37$ ton

Perhitungan jumlah ball :

Diameter bola baja 5 in = 0.127 m

Jari-jari bola baja $= \frac{0.127}{2} = 0.0635$ m

Volume bola $= (4/3)\,\pi\,R^3 = 0.001072\ m^3 = 1.0720$ L

Densitas bola (steel) = 4.8 gram/cm^3 **(Perry ed.7 20-33)**
= 4.8 kg/L

Berat (massa) Bola = 4.8 kg/L x 1.0720 L
= 5.1455 kg x

Berat total untuk baja ukuran 5 in = 4.37 ton
= 4366.67 kg

Jumlah baja ukuran 5 in $= \dfrac{4366.67}{5.1455}$
= 848.6317 Buah

Diameter bola baja 3.5 in = 0.0889 m

Jari-jari bola baja $= \dfrac{0.0889}{2} =$ 0.04445

Volume bola = (4/3) π R^3 = 0.00037 m^3 = 0.3677 L

Densitas bola (steel) = 4.8 gram/cm^3 **(Perry ed.7 20-33)**
= 4.8 kg/L

Berat (massa) Bola = 4.8 kg/L x 0.3677 L
= 1.7649 kg

Berat total untuk baja ukuran 5 in = 4.37 ton
= 4366.67 kg

Jumlah baja ukuran 5 in $= \dfrac{4366.67}{1.7649}$
= 2474.145 Buah

Diamater bola baja 2.5 in = 0.0635 m

Jari-jari bola baja $= \dfrac{0.0635}{2} =$ 0.03175 m

Volume bola = (4/3) π R^3 = 0.00013 m^3 = 0.1340 L

Densitas bola (steel) = 4.8 gram/cm^3 **(Perry ed.7 20-33)**
= 4.8 kg/L

Berat (massa) Bola = 4.8 kg/L x 0.1340 L
= 0.6432 kg

Berat total untuk baja ukuran 5 in = 4.37 ton
= 4366.67 kg

Jumlah baja ukuran 5 in $= \dfrac{4366.67}{0.6432}$

= 6789.053 Buah

Perhitungan kecepatan kritis

Nc = $76{,}6 / D^{0,5}$ **(Perry 7^{ed} : 20-32)**

dimana : Nc = Kecepatan kritis ; rpm

D = Diameter mill ; ft

$$Nc = \frac{76.6}{D^{0,5}}$$

$$= \frac{76.6}{5^{0,5}}$$

= 34.26 rpm

Kecepatan aktual = 60-80% dari kecepatan kritis (**Perry 7ed : 20-32)**

ditetapkan : N = 78% Nc

= 78% x 34.26

= 27 rpm

Ditetapkan kecepatan aktualnya = 27 rpm

Perhitungan power yang dibutuhkan :

Power = $D^{2,5}$ **(Perry 7^{ed} : 20-34)**

= $5^{2,5}$

= 56 hp

Spesifikasi :

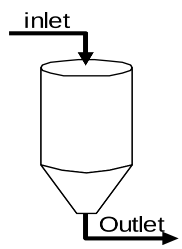
Fungsi	=	Menghaluskan kristal sampai ukuran 100 me
Type	=	Marcy ball mill
Dasar Pemilihan	=	Sesuai dengan jenis bahan dan kapasitas
Kapasitas	=	94.23 ton/hari
Rate maksimum	=	180 ton/hari
Diameter mill	=	5 ft
Panjang mill	=	7 ft
Kecepatan putaran aktual	=	27 rpm
Power	=	56 hp
Bahan ball	=	Stainless steel
Bahan konstruksi	=	Carbon steel C-283
Ukuran bola baja	=	5 & 3.5 & 2.5 in
Jumlah bola	=	5 in = 849 Buah
	=	3.5 in = 2474 Buah
	=	2.5 in = 6789 Buah
Jumlah	=	1 buah

42. SILO(F-371)

Fungsi : Menampung sementara Oleamida dari ball mill

Type : Silinder tegak dengan tutup bawah berbentuk conis

Dasar Pemilihan : Umum digunakan unruk menampung padatan



Komponen bahan masuk

Komponen	Massa (kg/jam)	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO$	3914.5146	0.9971	0.94
$C_{18}H_{34}O_2$	10.4462	0.0027	0.895
$CO(NH_2)_2$	0.4445	0.0001	1.32
$AlCl_3$	0.4178	0.0001	2.48
$CHCl_3$	0.0989	2.51874E-05	1.49
H_2O	0.0276	7.03095E-06	1
Total	**3926.0551**	**1.00**	**8.125**

$$\rho \text{ campuran} = \frac{1}{\sum \dfrac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62.43 \quad \text{lb/cuft}$$

$$= \frac{1}{\dfrac{0.9971}{0.9400} + \dfrac{0.0020}{0.895} + \dfrac{0.0001}{1.3200} + \dfrac{0.0001}{2.48} + \dfrac{0.0067}{1.49} + \dfrac{7E-06}{1}} \times 62.43 \quad \text{lb/cuft}$$

$= 58.84968$ lb/cuft

Rate Massa = 3926.055113 kg/jam

= 8655.3811 lb/jam

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

= 8655.3811 lb/jam

1.49 lb/cuft
= 5808.9806 cuft/jam

Direncanakan, waktu tinggal = 1 jam
Volume bahan = Rate volumetrik x waktu tinggal
= 5808.9806 x 1
= 5808.9806 cuft

Asumsi bahan mengisi 80% volume tangki, maka :

$$\text{Volume tangki} = \frac{\text{Volume bahan}}{80\%} = \frac{5808.9806}{80\%} = 7261.2258 \text{ cuft}$$

Menentukan dimensi tangki

Asumsi dimensi ratio H/D = 2 **(Ulrich T.4-27)**
H = 2 D

$$\text{Volume tangki} = \frac{\pi}{4} \times D^2 \times H$$

$7261.2258 = 0.785 \times D^2 \times 2\ D$
$7261.2258 = 1.57\ D^3$
$4624.9846 = D^3$
D = 16.6611 ft
= 199.9331 in
= 5.0783 m
H = 2 D
= 33.3222 ft
= 399.8662 in
= 10.1566 m

H bahan = 80% H
= 80% x 33.3222
= 26.6577 ft
= 8.1253 m
P operasi = 1 atm
= 14.7 psi

P design diambil 10% lebih besar dari P operasi untuk faktor keamanan
P design = 14.7 x 1.1
= 16.17 psi

Menentukan Tebal Minimum Shell

Tebal shell berdasarkan ASME code untuk cylindrical tank :

$$ts_{min} = \frac{P \quad X \quad ri}{f \quad E \; - \; 0.6 \quad P} + C$$

Keterangan :

ts_{min}	= tebal shell minimum	(in)	
P	= tekanan tangki	(psi)	
ri	= jari-jari tangki	(in; 1/2D) =	
C	= faktor korosi	(in: 1/8D)	**(Brownell, pg 254)**
E	= faktor pengelasan	(double welded; 0.8)	
f	= allowable stress, bahan konstruksi Carbon Steel SA-283 Grade C		
	maka, f all = 12650 psi		**(Brownell, T.13-1, pg 251)**

Asumsi tebal shell = 1/4 in

$$ts_{min} = \frac{P \quad x \quad ri}{f \quad E \; - \; 0.6 \quad P} + C$$

$$1/4 = \frac{16.17 \quad x \quad 99.9665}{f \quad x \quad 0.8 \; - \; 0.6 \quad x \quad 16.17} + 1/8$$

$$1/8 = \frac{1616.4590}{0.8 \quad f \; - \; 9.7020}$$

$$0.1 \quad f \; - \; 1.2128 = 1616.4590$$

$$0.1 \quad f = 1617.6718$$

$$f = 16176.7177 \text{ psi}$$

f hitung lebih kecil dari f *allowable* , jadi tebal shell 1/4 memenuhi

Menghitung Tutup Bawah Berbentuk Conical

Untuk tebal tutup atas disamakan dengan tebal tutup bawah, karena tutup bawah lebih banyak menerima beban

$$tc = \frac{P \quad x \quad Di}{2 \cos \alpha \,(f\,E - 0{,}6\,P)} + C$$

Dengan α = 30 °

Asumsi tebal *shell* = 1/4 in

$$tc = \frac{P \quad x \quad Di}{2 \cos \alpha \,(f\,E - 0{,}6\,P)} + C$$

$$1/4 = \frac{16.2 \quad x \quad 199.9331}{2 \;\; \cos 30 \quad (\quad f \quad x \quad 0.8 \; - \; 0.6 \quad x \quad 16.17 \;)} + 1/8$$

$$1/8 = \frac{3232.918043}{2 \quad ((\quad f \quad 0.8 \quad) \; - \; (\quad 9.7020 \quad)}$$

$$1/8 = \frac{3232.9180}{1.6000 \quad f \; - \; 19.4040}$$

$0.2 \; f - 2.4255 = 3232.9180$

$0.2 \; f = 3230.4925$

$f = 16152.4627$ psi

f hitung lebih kecil dari f *allowable* , jadi tebal shell 1/4 memenuhi

Tinggi Conical

$$h = \frac{tg\ \alpha \times (D - m)}{2}$$ **(Hesse, pers 4-17)**

Dengan : α = sudut conis 30 °

D = diameter tangki (ft)

m = flat sport diameter = 12 in = 1 ft

$$h = \frac{tg\ \alpha \times (D - m)}{2}$$

$$h = \frac{tg\ (30) \times (16.6611 - 1)}{2}$$

$$h = \frac{0.5774 \times 15.6611}{2}$$

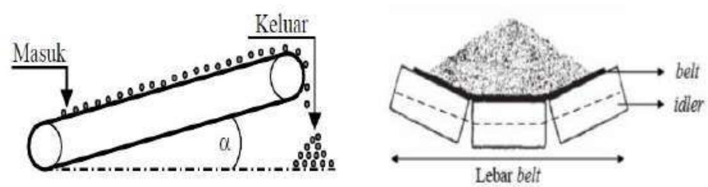
$h = 4.5210$ ft

Spesifikasi :

Fungsi	=	Menampung sementara oleamida dari ball mill
Type	=	Silinder tegak dengan tutup atas datar dan bawah conical
Dasar pemilihan	=	Umum digunakan untuk menampung padatan
Kapasitas	=	5808.9806 ft
Diameter tangki	=	16.6611 ft
Tinggi tangki	=	33.3222 ft
Tebal shell	=	1/4 in
Tebal tutup bawah	=	1/4 in
Tebal tutup atas	=	1/4 in
Tinggi conical	=	4.5210 ft
Cone conical	=	30 °
Jumlah	=	1 buah
Bahan konstruksi	=	Carbon Steel SA-283 Grade C

43. BELT CONVEYOR (J-372)

Fungsi = Memindahkan Oleamida ke gudang penyimpanan
Type = Thoughed belt on 45° idlers with rolls of equal
Dasar Pemilihan = Dipilih conveyor jenis belt sesuai dengan bahan



Rate massa	=	3,926.0551	lb/jam
	=	1,780.8469	kg/jam
	=	1.7808	ton/jam

Dari perry 7 ed, tabel 21-7 dan 21-4 dipilih belt conveyor dengan spesifikasi sebagai berikut:

Kapasitas maksimum		=	32	ton/jam
hP tiap 10 ft (linier ft)		=	0.34	hP
Belt	Width	=	14	in
	Trough width	=	9	in
	Skit seal	=	2	in
Belt plies		=	3 - 5	
Kecepatan belt		=	100	ft/menit

Sudut belt conveyor = 15 °
tg α = 0.267949

Asumsi :

Jarak Belt dengan Gudang = 15 ft = 4.572 m

$$\text{tg } \alpha = \frac{\text{tinggi}}{\text{jarak}}$$

$$0.267949192 = \frac{\text{tinggi}}{15}$$

Tinggi belt = 4.0192 ft
= 1.2251 m

Panjang belt = √((jarak belt)^2 + (tinggi belt)^2)
= 15.52914 ft
= 4.733283 m

Perhitungan power convetor

hP / 10 ft, lift = 0.34 hP / lift

$$\text{maka, hP} = \frac{15.5291}{10} \times 0.34$$

$$= 0.5280 \text{ hP}$$

Penambahan power untuk tripper = 2 hP

Maka power total = 0.5280 + 2

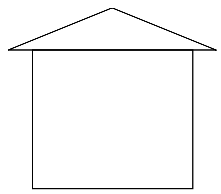
= 2.5280 hP

Spesifikasi :

Fungsi	=	Memindahkan Oleamida ke gudang penyimpanan
Type	=	Thoughed belt on 45° idlers with rolls of equal
Kapasitas maksimum	=	32 ton/jam
Belt	=	Width = 14 in
		Trough width = 9 in
		Skirt seal = 2 in
Belt speed	=	$\frac{1.7808}{32} \times 100$ ft/mnt = 5.5651
Panjang belt	=	15.5291 ft
Tinggi belt	=	4.0192 ft
Power	=	2.53 hP
Jumlah	=	1 buah

44. GUDANG OLEAMIDA (F-373)

Fungsi = Menyimpan produk Oleamida yang sudah dikemas
Type = Bangunan Segi 4
Dasar Pemilihan = Digunakan sebagai tempat penyimpan padatan
Kondisi Operasi = Tekanan = 1 atm
Suhu = 30 °C
Waktu penyimpanan = 7 hari



Perhitungan
Komposisi bahan masuk :

Komponen	Massa (kg/jam)	Fraksi Berat	ρ (gr/ml)
$C_{18}H_{35}NO$	3914.5146	0.9971	0.94
$C_{18}H_{34}O_2$	10.4462	0.0027	0.895
$CO(NH_2)_2$	0.4445	0.0001	1.32
$AlCl_3$	0.4178	0.0001	2.48
$CHCl_3$	0.0989	0.0000	1.49
H_2O	0.0276	0.0000	1
Total	**3925.9497**	**1**	**8.125**

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ campuran}}} \times 62.43 \text{ lb/cuft}$$

$$= \frac{1}{\frac{0.9971}{0.9400} + \frac{0.0010}{1.34} + \frac{0.0001}{1.3200} + \frac{0.0001}{2.48} + \frac{0.0000}{1.1} + \frac{0.0000}{1}} \times 62.43 \text{ lb/cuft}$$

$$= 58.80472 \text{ lb/cuft}$$

Rate Massa = 3925.949677 kg/jam
= 8655.1487 lb/jam

Rate Volumetrik $= \dfrac{\text{Rate massa}}{\text{Densitas}}$

$= \dfrac{8655.1487 \text{ lb/jam}}{58.8047 \text{ lb/cuft}}$

$= 147.1846$ cuft/jam

Direncanakan untuk 7 hari proses, 1 buah gudang,
sehinga volume bahan adalah

Volume bahan = Rate Volumetrik x Waktu tinggal
= 147.1846 cuft/jam x 24 x 7
= 24727.0129 cuft

Asumsi volume bahan mengisi 80% dari volume gudang (faktor keamanan)

Volume gudang $= \dfrac{\text{Volume bahan}}{80\%}$

$= \dfrac{24727.0129}{80\%}$ cuft

= 30908.7661 cuft

Dimensi gudang penyimpanan
Panjang = 2x
Lebar = x
Tinggi = x

Volume gudang = p x l x t
30908.7661 = 2 x^3
15454.3831 = x^3
x = 24.9087 ft

Sehingga :
Panjang = 49.8173 ft = 15.1843 m
Lebar = 24.9087 ft = 7.5922 m
Tinggi = 24.9087 ft = 7.5922 m

Luas Alas = p x l
= 49.8173 x 24.9087
= 1240.8838 ft^2

Volume Gudang = p x l x t
= 49.8173 x 24.9087 x 24.9087
= 30908.7661 cuft
= 874.7181 m^3

Spesifikasi :

Fungsi	=	Menyimpan produk oleamida yang sudah dikemas			
Type	=	Bangunan Segi 4			
Dasar Pemilihan	=	Digunakan sebagai tempat penyimpanan			
Kapasitas	=	30908.7661 cuft			
Panjang Gudang	=	49.8173 ft	=	15.1843	m
Lebar Gudang	=	24.9087 ft	=	7.5922	m
Tinggi Gudang	=	24.9087 ft	=	7.5922	m
Jumlah	=	1 buah			

APPENDIX D
ANALISIS EKONOMI

A. HARGA PERALATAN

Indeks harga peralatan berdasarkan pada Peters and Timmerhaus "Plant Design and Economic for Chemical Engineering". Perhitungan berdasarkan Marshall (All Industry), Chemical tabel D-1.

Tahun	Indeks
2010	550.8
2011	585.7
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	708.8
2022	816
2023	800.8

Sumber : CEPCI (Chemical Engineering Plant Cost Index) tahun 2023 Annual Index

Dengan metode least square dan data-data pada tabel diatas maka dilakukan pendekatan indeks harga pada tahun 2025

X = Tahun

Y = Indeks

	X	Y	X^2	Y^2	X.Y
	2010	550.8	4040100	303380.6	1107108
	2011	585.7	4044121	343044.5	1177843
	2012	584.6	4048144	341757.2	1176215
	2013	567.3	4052169	321829.3	1141975
	2014	576.1	4056196	331891.2	1160265
	2015	556.8	4060225	310026.2	1121952
	2016	541.7	4064256	293438.9	1092067
	2017	567.5	4068289	322056.3	1144648
	2018	603.1	4072324	363729.6	1217056
	2019	607.5	4076361	369056.3	1226543
	2020	596.2	4080400	355454.4	1204324
	2021	708.8	4084441	502397.4	1432485
	2022	816	4088484	665856.0	1649952
	2023	800.8	4092529	641280.6	1620018
Σ	**28231**	**8663**	**56928039**	**5465198.55**	**17472450**

Jumlah data = n = 14

Persamaan 17.21 Peters Timmerhaus

$$\sum\left(\bar{x}-x\right)^2 = \sum x^2 - \frac{\left(\sum x\right)^2}{n} = 227.5$$

$$\sum\left(\bar{y}-y\right)^2 = \sum y^2 - \frac{\left(\sum y\right)^2}{n} = 104781.664$$

Persamaan 17.20 Peters Timmerhaus

$$\sum\left(\bar{x}-x\right)\left(\bar{y}-y\right) = \sum xy - \frac{\sum x \sum y}{n} = 3712.55$$

$$b = \frac{\sum\left(\bar{x}-x\right)\left(\bar{y}-y\right)}{\sum\left(\bar{x}-x\right)^2} = 16.3189$$

Rata rata y = 618.8

Rata rata x = 2017

y = a + b (x - c)

= 618.8 + 16.319 (x - 2017)

= -32288.28549 + 16.319 x

Dari persamaan diatas diperoleh indeks harga pada tahun 2028 maka

= 806.4

$1 = Rp 16,555.91 **(http://kursdollar.net/)** per Oktober 2025

a. Harga Peralatan Produksi

Contoh perhitungan harga peralatan

Bucket Elevator :

Harga pada tahun 2021 = $ 10,800.00

(www.alibaba.com)

Harga pada tahun 2028 = $\left(\frac{\text{Indeks harga saat ini}}{\text{Indeks harga tahun A}} \right)$ x Harga Tahun A

= $\left(\frac{806.4459}{708.8} \right)$ x $ 10,800.00

= $ 12,287.8331

= Rp 203,436,259

Tabel Harga Peralatan Proses					
No	Nama Alat	Harga		Jumlah	Harga Total
		US $ 2021	US $ 2028		US $
F-110	Gudang Urea	45000	51199.3	1	51199.3045
J-111	Screw Conveyor - 1	27000	30719.58	1	30719.5827
J-112	Bucket Elevator - 1	35000	39821.68	1	39821.6813
F-113	Hopper - 1	12000	13653.15	1	13653.1479
F-120	Tangki Asam Oleat	57000	64852.45	1	64852.4524
L-121	Pompa - 1	12500	14222.03	1	14222.029
E-122	Heater - 1	14000	15928.67	1	15928.6725
M-130	Melter	150000	170664.3	1	170664.348
L-131	Pompa - 2	12500	14222.03	1	14222.029
F-140	Gudang $ALCl_3$	45000	51199.3	6	307195.827
J-141	Screw Conveyor - 2	17000	19341.96	1	19341.9595
J-142	Bucket Elevator - 2	12000	13653.15	1	13653.1479
F-143	Hopper - 2	6000	6826.574	1	6826.57393
F-150	Tangki Kloroform	92000	104674.1	8	837393.069
L-151	Pompa - 3	12500	14222.03	1	14222.029
R-210	Reaktor	245000	278751.8	1	278751.769
G-211	Blower-1	55000	62576.93	1	62576.9277
E-212	Cooler-1	45000	51199.3	1	51199.3045
L-213	Pompa - 4	10500	11946.5	1	11946.5044
E-214	Cooler-2	67000	76230.08	1	76230.0756
D-220	Absorber	175000	199108.4	1	199108.406
F-221	Tangki Penampung-1	12000	13653.15	1	13653.1479
M-310	Mixer	225000	255996.5	1	255996.523
L-311	Pompa - 5	12500	14222.03	1	14222.029
H-320	Filter Press	75000	85332.17	2	170664.348
F-321	Bak Penampung	23000	26168.53	1	26168.5334
L-322	Pompa - 6	12500	14222.03	1	14222.029
V-330	Evaporator	186000	211623.8	1	211623.792
L-331	Pompa - 7	12500	14222.03	1	14222.029
E-332	Kondensor	120000	136531.5	1	136531.479
X-340	Crystalizer	280000	318573.5	1	318573.45
H-350	Centrifuge	198000	225276.9	1	225276.94
F-351	Tangki Penampung-2	12000	13653.15	2	27306.2957
J-352	Screw Conveyor - 3	7000	7964.336	1	7964.33626
B-360	Rotary Dryer	75000	85332.17	1	85332.1742
G-361	Blower-2	5000	5688.812	1	5688.81161
D-362	Molecular Sieve	18000	20479.72	1	20479.7218
E-363	Heater 2	14000	15928.67	1	15928.6725
J-364	Cooling Screw Conve	8000	9102.099	1	9102.09858
J-365	Bucket Elevator - 3	11000	12515.39	1	12515.3855
C-370	Ball Mill	216000	245756.7	1	245756.662
F-371	Silo	321000	365221.7	1	365221.705

J-372	Belt Conveyor	17000	19341.96	1	19341.9595
F-373	Gudang Oleamida	40000	45510.49	1	45510.4929
TOTAL					4555031.46

Tabel Harga Peralatan Utilitas					
No	Nama Alat	Harga		Jumlah	Harga Total
		US $ 2021	US $ 2025		US $
L-111	Pompa-1	16700	19000.63	1	19000.6308
F-110	Bak Penampung Air Sunga	35000	39821.68	1	39821.6813
L-112	Pompa-2	16700	19000.63	1	19000.6308
D-210	Tangki Koagulasi	282300	321190.3	1	321190.304
D-220	Tangki Flokulasi	282300	321190.3	1	321190.304
L-221	Pompa-3	16700	19000.63	1	19000.6308
H-310	Clarifier	97700	111159.4	1	111159.379
F-311	Bak penampung Flok	6000	6826.574	1	6826.57393
F-312	Bak Penampung Air\	8620	9807.511	1	9807.51122
L-313	Pompa-4	16700	19000.63	1	19000.6308
H-320 A	Sand Filter-1	45100	51313.08	1	51313.0807
H-320 B	Sand Filter-2	45100	51313.08	1	51313.0807
F-321	Bak Penampung	8620	9807.511	1	9807.51122
L-322	Pompa-5	4900	5575.035	1	5575.03538
L-323	Pompa-6	11500	13084.27	1	13084.2667
L-324	Pompa-7	14700	16725.11	1	16725.1061
F-325	Bak Air Sanitasi	5420	6166.672	1	6166.67179
F-326	Bak Air Pendingin	6550	7452.343	1	7452.34321
L-327	Pompa-8	14700	16725.11	1	16725.1061
F-328	Bak Penampung	7360	8373.931	1	8373.93069
L-329	Pompa-9	14700	16725.11	1	16725.1061
H-330	kation Exchanger	270100	307309.6	1	307309.603
L-331	Pompa-10	11500	13084.27	1	13084.2667
H-340	Anion Exchanger	250200	284668.1	1	284668.133
F-341	Tangki Air Demin	4050	4607.937	1	4607.93741
L-342	Pompa-11	19700	22413.92	1	22413.9177
L-343	Pompa-12	11500	13084.27	1	13084.2667
P-350	Cooling Tower	638500	726461.2	1	726461.243
L-351	Pompa-13	14700	16725.11	1	16725.1061
E-360	Boiler	1875000	2133304	1	2133304.35
TOTAL		4052620	4610918	30	4610918.34

Total Biaya Peralatan	=	Total Harga Alat Proses	+	Total Harga Alat Utilitas	
	=	$	4,555,031.46	$	4,610,918.34
	=	$	9,165,949.80		
	=	$	151,750,639,955.87		

Harga Bahan Baku dan Produk

a. Harga Bahan Baku

1. Asam Oleat

Kebutuhan	=	4220.686753	Kg/Jam
	=	33427839.09	Kg/Tahun
	=	33427.83909	Ton/Tahun

Harga Per Ton = Rp 13,692,000.00 (PT. Cisande Raya Chemical)
Biaya Per Tahun = Rp 457,693,972,761.92

2. Urea

Kebutuhan	=	898.0184581	Kg/Jam
	=	7112306.188	Kg/Tahun
	=	7112.306188	Ton/Tahun

Harga Per Ton = Rp 8,430,000
Biaya Per Tahun = Rp 59,956,741,168.67

3. ALCl3

Kebutuhan	=	42.20686753	Kg/Jam
	=	334278.3909	Kg/Tahun
	=	334.2783909	Ton/Tahun

Harga Per Ton = Rp 17,792,000.00
Biaya Per Tahun = Rp 5,947,481,130.13

4. CHCl3

Kebutuhan	=	37.96	Kg/Jam
	=	300616.4384	Kg/Tahun
	=	300.6164384	Ton/Tahun

Harga Per Ton = Rp 20,990,000.00
Biaya Per Tahun = Rp 6,309,939,041.17

5. Total Biaya Bahan Baku

Biaya Bahan Baku = Rp 529,908,134,101.89

b. Harga Jual Produk Oleamida

Hasil Produksi = 35000 Ton/Tahun
Harga Produk = Rp 28,500 Per Kg
= Rp 28,500,000 Per Ton
= Rp 997,500,000,000 pertahun

Harga Jual Produk NH_3 dan CO_2

Hasil Produksi = 649770.9 Ton/Tahun
Harga Produk = Rp 2,200 Per Kg

= Rp 2,200,000 Per Ton
= Rp 1,429,496,000,801 pertahun
Harga Jual Per Tahun = Rp 2,426,996,000,801

c. Biaya Pengemasan
Hasil Produksi = 35000000.00 Kg/Tahun
Kapasitas Karung = 10 Kg
Kebutuhan Karung = 3500000 Unit/Tahun
Harga Karung = Rp 1,500
Biaya Pengemasan = Rp 5,250,000,000 Per Tahun

Harga Jual Per Tahun = Rp 2,426,996,000,801 Per Ton
Biaya Pengemasan = Rp 5,250,000,000 Per Tahun
Total Biaya Penjualar = Rp 2,421,746,000,801 Per Tahun

d. Gaji Karyawan

Jabatan	Jumlah (orang)	Tunjangan/org (Rp)	Tunjangan/bln (Rp)	Gaji/thn (Rp)
Direktur Utama	1	55,000,000	55,000,000	715,000,000
Sekretaris	1	10,000,000	10,000,000	130,000,000
Staff ahli	4	20,000,000	80,000,000	1,040,000,000
Direktur Produksi & Teknik	1	40,000,000	40,000,000	520,000,000
Direktur Keuangan dan Administrasi	1	40,000,000	40,000,000	520,000,000
General Manager	1	30,000,000	30,000,000	390,000,000
Manager Produksi dan Teknik	1	20,000,000	20,000,000	260,000,000
Manager Keuangan dan Administrasi	1	20,000,000	20,000,000	260,000,000
Kabag Produksi	1	10,000,000	10,000,000	130,000,000
Kabag Teknik	1	10,000,000	10,000,000	130,000,000
Kabag Keuangan	1	10,000,000	10,000,000	130,000,000
Kabag Umum	1	10,000,000	10,000,000	130,000,000
Kabag Pemasaran	1	10,000,000	10,000,000	130,000,000
Kasi Produksi & Proses	1	8,000,000	8,000,000	104,000,000
Kasi Riset & Pengembar	1	8,000,000	8,000,000	104,000,000
Kasi Laboratorium	1	8,000,000	8,000,000	104,000,000
Kasi Utilitas & Energi	1	8,000,000	8,000,000	104,000,000
Kasi Pemeliharaan	1	8,000,000	8,000,000	104,000,000
Kasi Gudang & Bengkel	1	8,000,000	8,000,000	104,000,000
Kasi Personalia	1	8,000,000	8,000,000	104,000,000
Kasi Keamanan	1	8,000,000	8,000,000	104,000,000
Kasi Humas	1	8,000,000	8,000,000	104,000,000
Kasi K3	1	8,000,000	8,000,000	104,000,000

Kasi Administrasi	1	8,000,000	8,000,000	104,000,000
Kasi Keuangan	1	8,000,000	8,000,000	104,000,000
Kasi Pemasaran dan Penjualan	1	8,000,000	8,000,000	104,000,000
Kasi bagian Pembelian	1	8,000,000	8,000,000	104,000,000
Karyawan Proses	48	6,000,000	288000000	3,744,000,000
Karyawan Bagian K3	8	5,000,000	40,000,000	520,000,000
Karyawan Laboratorium	8	5,000,000	40,000,000	520,000,000
Karyawan Utilitas	28	5,000,000	140000000	1,820,000,000
Karyawan Pemeliharaan	8	4,000,000	32,000,000	416,000,000
Karyawan Riset dan Pengembangan	3	6,000,000	18,000,000	234,000,000
Karyawan Pembelian	2	4,000,000	8,000,000	104,000,000
Karyawan Administrasi	3	4,000,000	12,000,000	156,000,000
Karyawan Keuangan	3	4,000,000	12,000,000	156,000,000
Karyawan Pemasaran	4	4,000,000	16,000,000	208,000,000
Karyawan Personalia	4	4,000,000	16,000,000	208,000,000
Karyawan Keamanan	12	3,500,000	42,000,000	546,000,000
Karyawan Humas	2	4,000,000	8,000,000	104,000,000
Karyawan Gudang	8	4,000,000	32,000,000	416,000,000
Karyawan Pembersih	8	3,000,000	24,000,000	312,000,000
Dokter	2	8,000,000	16,000,000	208,000,000
Perawat	3	5,000,000	15,000,000	195,000,000
Sopir	5	3,000,000	15,000,000	195,000,000
Pesuruh	5	2,800,000	14,000,000	182,000,000
Jumlah	194	481,300,000	1,245,000,000	16,185,000,000

Total gaji pegawai dalam 1 tahun = Rp 16,185,000,000.00
(1 tahun = 13 kali gaji)

e. Biaya Utilitas

1. Air

Kebutuhan air per hari = 11928.06 m³/hari
Biaya air per hari = 11928.06 x Rp 7,200 /m³
Rp 85,882,030 /hari
= Rp 28,341,069,980 /tahun

2. $Al_2(SO_4)_3$

Kebutuhan $Al_2(SO_4)_3$ per taun = 8502321 Kg/Tahun
Harga $Al_2(SO_4)_3$ = Rp 9,000 /Kg (PT Lautan Luas)
Biaya $Al_2(SO_4)_3$ Per Taun = 76520888946 /Tahun

3. PAC

Kebutuhan PAC per tahun = 12753.48 Kg/Tahun

Harga PAC = Rp 18,000 /Kg (PT Lautan Luas)
Biaya PAC per tahun = Rp 229,562,667 /Tahun

4. Dowex Kation
   Kebutuhan Dowex Kation = 8164634.73 m^3/tahun
   Harga Dowex = Rp 37,000 /m^3 **(Ady Water)**
   Biaya Dowex Kation per tahu = 3.02091E+11 /Tahun

5. HCL 33%
   Kebutuhan HCL 33% = 585181.6 Kg/tahun
   Harga HCL 33% = Rp 10,000 /Kg **(PT Lautan Luas)**
   Biaya HCL 33% per tahun = 5851816380 /Tahun

6. NaOH
   Kebutuhan NaOH = 1184549 Kg/Tahun
   Harga NaOH = Rp 13,800 /Kg **(PT Lautan Luas)**
   Biaya NaOH/tahun = Rp 16,346,783,066 /Tahun

7. Chlorine = 3,450 Kg/Tahun
   Harga Chlorine = Rp 31,000 /Kg **(PT Lautan Luas)**
   Biaya Chlorine/tahun = Rp 106,954,650 /Tahun

8. Bahan Bakar (fuel oil)
   Kebutuhan Bahan Bakar = 6868217.58 L/Tahun
   Harga Bahan Bakar = Rp 26,400 /L (solarindustri.com)
   Biaya Bahan Bakar per tahun = Rp 181,320,944,233 L/Tahun

9. Listrik
   Kebutuhan Listrik = 3179.707 kWh
   Harga Listrik = Rp 1,400 kWh **(PLN per Februari 2025)**
   Biaya Listrik per taun = Rp 35,256,591,338 /Tahun
   Biaya total utilitas per tahun = Rp 646,066,096,125

f. Harga Tanah Dan Bangunan
   Luas Tanah = 18378 m^2
   Harga Tanah per m^2 = Rp 1,852,200 ***www.realoka.com***
   Biaya Tanah = Rp 34,039,731,600

   Luas Bangunan Pabrik = 10100 m^2
   Harga Bangunan Pabrik per m^2 = Rp 5,000,000
   kontraktorsandwichpanel.com
   Biaya Bangunan Pabrik = Rp 50,500,000,000

   Luas Bangunan Gedung = 2940 m^2
   Harga Bangunan Gedung per m^2 = Rp 3,200,000 ***lidirkonstruksi.com***

Biaya Bangunan Gedung	=	Rp	9,408,000,000
Total Biaya Bangunan	=	Rp	59,908,000,000
Total Biaya Bangunan & Tanah	=	Rp	93,947,731,600