APPENDIX A
PERHITUNGAN NERACA MASSA

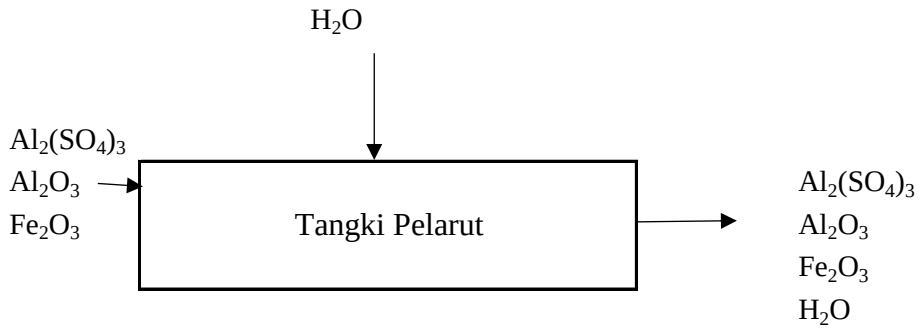
Kapasitas produksi = 100000 ton/tahun
= 100000000 kg/tahun
Waktu Operasi = 1 tahun
= 330 hari/tahun 1 hari proses
= 24 jam operasi,
Produk Amonia Alum = 12626,26263 kg/jam

Satuan Massa = kg
Basis = 6908,630147 kg aluminium sulfat

Data Berat Molekul (BM) : (Perry, 2008)

Komponen	kg/kmol
$Al_2(SO_4)_3$	342
Al_2O_3	102
Fe_2O_3	159,69
H_2SO_4	98,08
$(NH_4)_2SO_4$	132
H_2O	18
$Al_2(SO_4)_2.(NH_4)_2SO_4.24H_2O$	906

1. TANGKI PELARUT 1 (M-120)



Feed masul = 6908,63 kg aluminium sulfat

Komposisi Aluminium Sulfat

Komposisi	% Berat
$Al_2(SO_4)_3$	76,510%
Al_2O_3	22,819%
Fe_2O_3	0,671%

(Othmer,1965)

Komposisi Aluminium Sulfat , yang masuk ke mixer

$Al_2(SO_4)_3$	=	76,510%	x	6908,630147	=	5285,793	kg
Al_2O_3	=	22,819%	x	6908,630147	=	1576,480	kg
Fe_2O_3	=	0,671%	x	6908,630147	=	46,357	kg

Data kelarutan bahan pada 30°C dari (Perry 2008)

Komponen	Kelarutan (per 100 bagian H_2O)
$Al_2(SO_4)_3$	40,4
Al_2O_3	tidak larut
Fe_2O_3	tidak larut

Kelarutan $Al_2(SO_4)_3$, pada 30°C = 40,4 kg/100 kg H_2O

Berat $Al_2(SO_4)_3$ = 5285,79293 kg

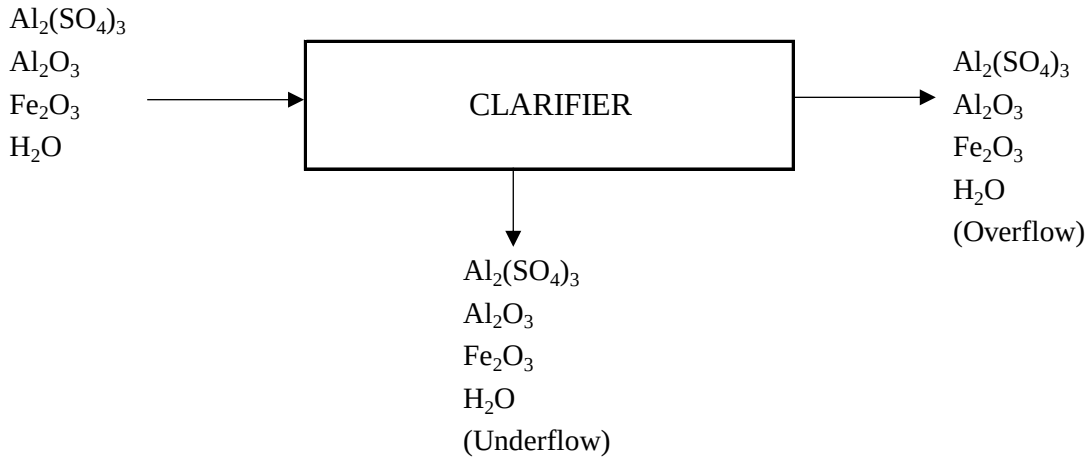
H_2O yang di butuhkan = $\frac{5285,79293}{40,4} \times 100$

= 13083,646 kg

Neraca Massa

Massa Masuk		Massa Keluar	
Komponen	**kg**	**Komponen**	**kg**
Dari tangki penampung		Bahan masuk clarifier	
$Al_2(SO_4)_3$	5285,793	$Al_2(SO_4)_3$	5285,793
Al_2O_3	1576,480	Al_2O_3	1576,480
Fe_2O_3	46,357	Fe_2O_3	46,357
		H_2O	13083,646
H_2O dari utilitas	13083,646		
Total	**19992,3**	**Total**	**19992,3**

2. CLARIFIER (H-122)



Komposisi yang keluar dari tangki pelarut 1

Komposisi	kg
$Al_2(SO_4)_3$	5285,793
Al_2O_3	1576,480
Fe_2O_3	46,357
H_2O	13083,646
Total	**19992,3**

Asumsi:
1. Sebesar 5% Al2(SO4)3 produk terbawa solid (Ludwig, 1964)
2. Tidak ada produk solid terbawa liquid

Komposisi liquid terikut solid sebesar :

Al2(SO4)3	5285,79293	x	5%	=	264,290 kg
H2O =	13083,6459	x	5%	=	654,182 kg
Total					**918,472** kg

Komposisi produk underflow :

Komposisi	kg
$Al_2(SO_4)_3$	264,290
Al_2O_3	1576,480
Fe_2O_3	46,357
H_2O	654,182
Total	**2541,31**

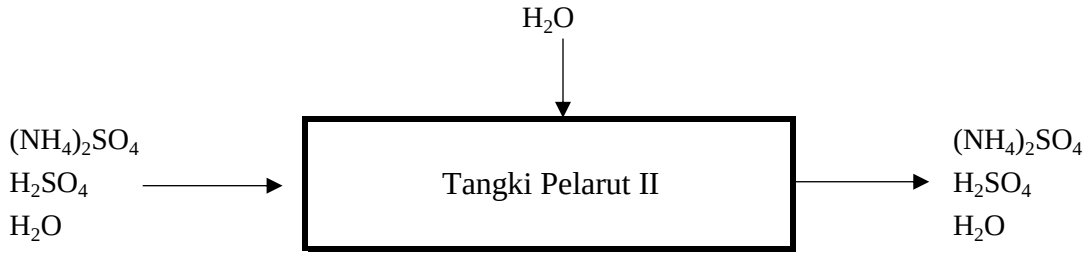
Komposisi produk overflow:

Komposisi	kg
Al2(SO4)3	5021,503
H2O	12429,464
Total	**17450,97**

Neraca Massa

Massa masuk		Massa keluar	
Komponen	**kg**	**Komponen**	**kg**
Dari tangki pelarut 1		Produk underflow	
$Al_2(SO_4)_3$	5285,793	$Al_2(SO_4)_3$	264,290
Al_2O_3	1576,480	Al_2O_3	1576,480
Fe_2O_3	46,357	Fe_2O_3	46,357
H_2O	13083,646	H_2O	654,182
	19992,3		2541,309
		Produk overflow	
		$Al_2(SO_4)_3$	5021,503
		H_2O	12429,464
			17450,967
Total	**19992,3**	**Total**	**19992,3**

3. TANGKI PELARUT II (M-140)



Konsentrasi Ammonium Sulfat

Komposisi	kg
$(NH_4)_2SO_4$	99,81%
H_2SO_4	0,03%
H_2O	0,16%

(PT Petrokimia Gresik Pabrik ZA I/III)

Dari keyes, hal 67 ditentukan perbandingan $Al_2(SO_4)_3$ dan $(NH_4)_2SO_4$ ke reaktor sebesar

Aluminium Sulfat 760 lb 344,66 kg
Ammonium Sulfat 290 lb 133,33 kg

$(NH_4)_2SO_4$ yang dibutuhkan $= \frac{133,33}{344,66} \times 6908,6$

$= 2672,569$

Larutan ammonium sulfat masuk reaktor $= 2677,549$

Komposisi (NH4)2SO4 masuk ke reaktor

$(NH_4)_2SO_4$	=	99,81%	x	2677,54932	=	2672,569
H_2SO_4	=	0,03%	x	2677,54932	=	0,723
H_2O	=	0,16%	x	2677,54932	=	4,284

Data kelarutan bahan pada 30 C dari (Perry, 2008)

Komponen	Kelarutan (per 100 bagian H_2O)
$(NH_4)_2SO_4$	78

Kelarutan $(NH_4)_2SO_4$ pada suhu 30°C

Berat $(NH_4)_2SO_4$ = 2672,569

H_2O yang dibutuhan $= \frac{2672,569}{78} \times 100$

$= 3426,371$ kg

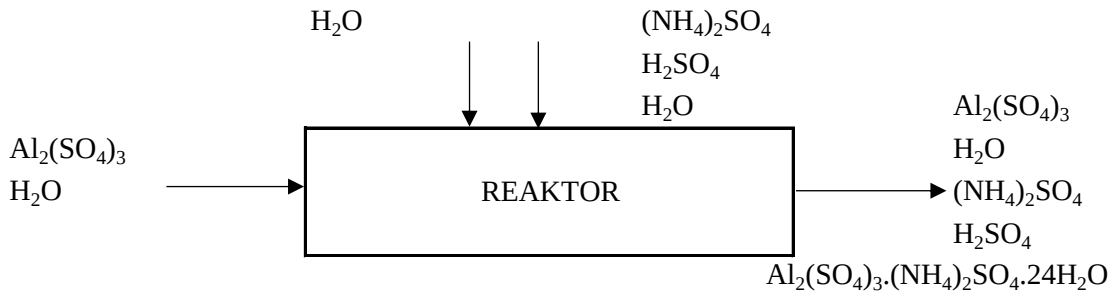
Total H2O yang ada = 4,284 + 3426,371

= 3430,655 kg

Neraca Massa

Massa Masuk		Massa Keluar	
Komponen	**kg**	**Komponen**	**kg**
Tangki penampung		Bahan masuk reaktor	
$(NH_4)_2SO_4$	2672,5691	$(NH_4)_2SO_4$	2672,5691
H_2SO_4	0,7229	H_2SO_4	0,7229
H_2O	4,2841	H_2O	3430,6547
	2677,5761		
H_2O dari utilitas	3426,3706		
Total	**6103,9467**	**Total**	**6103,9467**

4. REAKTOR (R-210)



Komposisi bahan dari clarifier

Komposisi	kg
$Al_2(SO_4)_3$	5021,503
H_2O	12429,464
Total	**17450,97**

Komposisi bahan dari tangki pelarut II

Komposisi	kg
$(NH_4)_2SO_4$	2672,569
H_2SO_4	0,723
H_2O	3430,655
Total	**6103,95**

Reaksi yang terjadi

$Al_2(SO_4)_3 + (NH_4)_2SO_4 + 24H_2O \longrightarrow Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$

Konversi : 95%

$Al_2(SO_4)_3$ yang tersedia	=	5021,503	kg		
	=	14,683	kmol		
$Al_2(SO_4)_3$ yang bereaksi	=	95%		x	14,683
	=	13,949	kmol		
	=	4770,4281	kg		
$(NH_4)_2SO_4$ yang bereaksi	=	1		x	13,949
	=	13,949	kmol		
	=	1841,218	kg		
H_2O yang betreaksi	=	24		x	13,949

= 334,767 kmol
= 6025,804 kg

$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ yang terbentuk = 1 x 13,949
= 13,949 kmol
= 12637,450 kg

$Al_2(SO_4)_3$ yang tersisa = 5021,503 - 4770,428
= 251,075 kg

$(NH_4)_2SO_4$ yang tersisa = 2672,569075 - 1841,218
= 831,351 kg

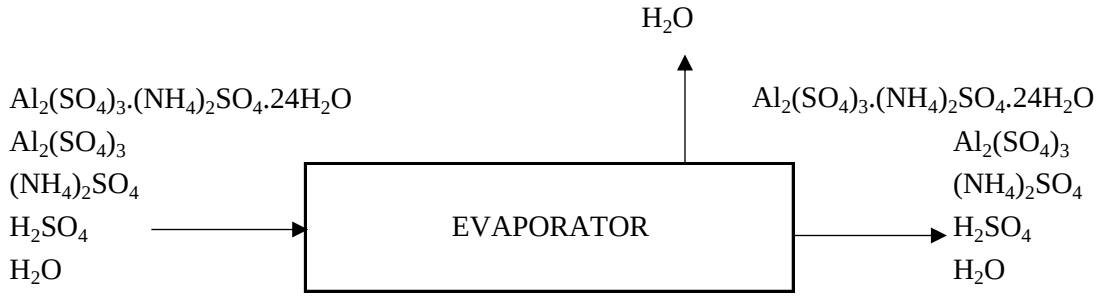
Jumlah H_2O yang masuk reaktor = H_2O $Al_2(SO_4)_3$ + $(NH_4)_2SO_4$ + H_2O Reaksi
= 15860,118 + 6025,804
= 21885,92 kg

H_2O sisa = 21885,92 - 6025,804
= 15860,118 kg

Neraca Massa

Massa Masuk		**Massa Keluar**	
Komponen	**kg**	**Komponen**	**kg**
Bahan dari clarifier		Bahan keluar reaktor	
$Al_2(SO_4)_3$	5021,503	$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12637,450
H_2O	12429,464	$Al_2(SO_4)_3$	251,075
	17450,967	$(NH_4)_2SO_4$	831,351
		H_2SO_4	0,723
		H_2O	15860,118
Bahan dari T.Pelarut II			29580,72
$(NH_4)_2SO_4$	2672,569		
H_2SO_4	0,723		
H_2O	3430,655		
	6103,947		
H_2O dari utilitas	6025,804		
Total	**29580,7**	**Total**	**29580,7**

5. EVAPORATOR (V-320)



Kondisi Operasi :

Tekanan operasi = 1 atm (atmospheric pressure)

Suhu operasi = 100°C (berdasarkan titik didih air)

Komposisi bahan masuk ke evaporator

Komponen	Reaktor (kg/jam)	Fraksi
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12637,4499	0,42722
$Al_2(SO_4)_3$	251,0752	0,00849
$(NH_4)_2SO_4$	831,3512	0,02810
H_2O	15860,1183	0,53616
H_2SO_4	0,7229	0,00002
Total	**29580,7175**	**1**

Kepekatan feed = 42,72%

Dalam evaporator larutan di pekatkan hingga = 55%

Neraca massa *over all*

$F = L + V$

$F \cdot X_F = L \cdot X_L + V \cdot X_V$

Dimana :

X_F = Total filtrat dalam feed / total feed

X_L = Filtrate dalam liquid

V = Vapour

L = Umpan ke evaporator

$F \times X_F = L \times X_L$

$29580{,}72 \times 42{,}72\% = L \times 55\%$

$$\frac{12637{,}45}{0{,}55} = L$$

$L = 22977{,}18$ kg/jam (Larutan pekat)

Berat bahan non air pada feed = berat feed - berat air

= 29580,72 - 15860,118
= 13720,599 kg/jam

Berat air pada produk = berat larutan akhir (L) - berat bahan non air
= 22977,182 - 13720,599
= 9256,582 kg/jam

Berat air pada feed = 15860,118
Berat air yang menguap = 15860,118 - 9256,582
= 6603,536 kg/jam

Neraca Massa

Massa Masuk		Massa Keluar	
Komponen	**kg**	**Komponen**	**kg**
Larutan masuk evaporator		Larutan ke kristallizr	
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12637,450	$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12637,450
$Al_2(SO_4)_3$	251,075	$Al_2(SO_4)_3$	251,075
$(NH_4)_2SO_4$	831,351	$(NH_4)_2SO_4$	831,351
H_2O	15860,118	H_2O	9256,582
H_2SO_4	0,723	H_2SO_4	0,723
	29580,717		22977,182
		H_2O yang menguap	6603,536
Total	**29580,72**	**Total**	**29580,72**

6. KRISTALIZER (X-330)

Komposisi bahan masuk kristalizer:

Komponen	kg
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12637,450
$Al_2(SO_4)_3$	251,075
$(NH_4)_2SO_4$	831,351
H_2O	9256,582
H_2SO_4	0,723
Total	**22977,18**

Perhitungan :

Penentuan Kristal yang terbentuk

Dengan metode example 1. (Perry 7ed), hal. 18-37, dengan persamaan :

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

Dengan :
- P = Berat Kristal
- R = Ratio BM dari kristal/larutan
- S = Solubility pada mother liquor dalam 100 kg pelarut
- Wo = Berat bahan yang akan dikristalkan pada feed
- Ho = Total bahan yang bersifat liquid pada feed
- E = Evaporation

Perhitungan :

Penguapan H_2O

Asumsi tidak terjadi penguapan H_2O

H_2O yang menguap = 0 kg

Ratio BM kristal dengan larutan (R) :

BM $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ = 906 kg/mol

BM $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ = 906 kg/mol

R = 906/906

= 1

Solubility kristal pada mother liquor (S):

Kelarutan pada mother liquor (suhu 30°C) = $\frac{10,94 \text{ gr}}{100 \text{ gr } H_2O}$

(Perry, ed 8th Table 2-122)

Sehingga kelarutan kristal pada mother liquor :

$$S = \frac{10,94}{100} = 0,11$$

Berat $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ yang akan terkristalkan pada feed (Wo) :

Wo = 12637,4499 kg

Total bahan yang bersifat liquid pada feed (Ho) :

Ho = 9256,5824 kg

Evaporation (E) :

E = H_2O yang menguap = 0

maka jumlah kristal yang terbentuk adalah :

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

$$= 1 \times \frac{(100 \times 1259,0672) - (0.11 \times (9508,1418 - 0))}{100 - (0.11\ (1-1))}$$

$$= 1 \times \frac{1262732,322}{100,0000}$$

= 12627,323 kg

Jadi,

Berat kristal $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ = 12627,3 kg

Berat $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ pada feed = 12637,4 kg

$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ yang terkristalisasi

= 0,98 x 12637,4 (Perry 7ed, 18-36)

= 12384,7 kg

Berat H_2O pada kristal = 12627,3 - 12384,701

= 242,6223 kg

Berat Al2(SO4)3.(NH4)2SO4.24H2O tidak terkristal

= Berat $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ pada feed - Berat kristal $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$

= 12637,45 - 12627,323

= 10,1267 kg

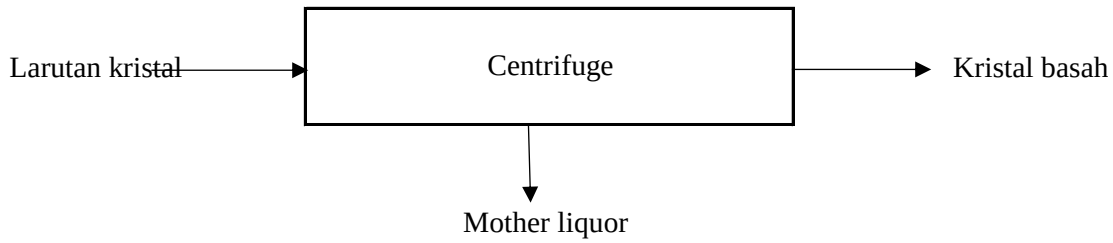
Sisa H_2O ke centrifuge = 9256,58 - 0

= 9256,5824 kg

Neraca Massa

Massa Masuk		Massa Keluar	
Komponen	**kg**	**Komponen**	**kg**
Bahan masuk kristalizer		Bahan larut dalam air	
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12637,450	$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	10,127
$Al_2(SO_4)_3$	251,075	$Al_2(SO_4)_3$	251,075
$(NH_4)_2SO_4$	831,351	$(NH_4)_2SO_4$	831,351
H_2O	9256,582	H_2SO_4	0,723
H_2SO_4	0,723	H_2O	9256,582
	22977,182		10349,858
		Bahan tak larut dalam air	
		$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12627,323
Total	**22977,18**	**Total**	**22977,18**

7. CENTRIFUGE (H-340)



Komposisi feed masuk

Komposisi	kg
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12637,450
$Al_2(SO_4)_3$	251,075
$(NH_4)_2SO_4$	831,351
H_2O	9256,582
H_2SO_4	0,723
Total	**22977,18**

Asumsi :
Liquid terikud solid = 2% (Perry, 2008)
Maka liquid keluar = 98% terdiri dari:

Total liquid masuk centrifuge

$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	=	10,127 kg
$Al_2(SO_4)_3$	=	251,075 kg
$(NH_4)_2SO_4$	=	831,351 kg
H_2O	=	9256,582 kg
H_2SO_4	=	0,723 kg
Total		**10349,86 kg**

Komposisi liquid terikut dalam kristal

$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$=	10,127	x	2%	=	0,203
$Al_2(SO_4)_3$	=	251,075	x	2%	=	5,022
$(NH_4)_2SO_4$	=	831,351	x	2%	=	16,627
H_2O	=	9256,582	x	2%	=	185,132
H_2SO_4	=	0,723	x	2%	=	0,0145
Total						**206,997**

Komposisi filtrat

Filtrat	=	liquid feed	-	liquid dalam kristal		
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ =	10,127	-	0,203	=	9,924
$Al_2(SO_4)_3$	=	251,075	-	5,022	=	246,054
$(NH_4)_2SO_4$	=	831,351	-	16,627	=	814,724
H_2O	=	9256,582	-	185,132	=	9071,451
H_2SO_4	=	0,723	-	0,0145	=	0,708
Total						**10142,861**

Komposisi cake

Solid kelua	=	berat solid	+	berat liquid terikut solid		
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ =	12627,323	+	0,203	=	12627,526
$Al_2(SO_4)_3$	=	0	+	5,022	=	5,022

$(NH_4)_2SO_4$	=	0	+	16,627	=	16,627
H_2O	=	0	+	185,132	=	185,132
H_2SO_4	=	0	+	0,0145	=	0,0145
Total						**12834,320**

Neraca Massa

Massa Masuk		**Massa Keluar**	
Komponen	**kg**	**Komponen**	**kg**
Baham masuk centrifuge		Bahan keluar centrifuge	
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12637,450	$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12627,526
$Al_2(SO_4)_3$	251,075	$Al_2(SO_4)_3$	5,022
$(NH_4)_2SO_4$	831,351	$(NH_4)_2SO_4$	16,627
H_2O	9256,582	H_2O	185,132
H_2SO_4	0,723	H_2SO_4	0,0145
	22977,182		12834,320
		Mother liquor	
		$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	9,924
		$Al_2(SO_4)_3$	246,054
		$(NH_4)_2SO_4$	814,724
		H_2O	9071,451
		H_2SO_4	0,708
			10142,861
Total	**22977,18**	**Total**	**22977,18**

8. ROTARY DRYER (B-350)

Kondisi Operasi :

Tekanan = 1 atm

Suhu = 120^oC (berdasarkan suhu udara masuk)

Komposisi bahan masuk :

Komposisi	**kg**
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12627,526
$Al_2(SO_4)_3$	5,022
$(NH_4)_2SO_4$	16,627
H_2O	185,132
H_2SO_4	0,0145
Total	**12834,320**

Kadar air yang di harapkan pada produk akhir = 0,50%
Asumsi kehilangan solid (terikut udara) = 1% (Ludwg,1964)

Berat H_2O pada feed = 185,132 kg
Berat solid kering pada feed = 12834,320 - 185,132
= 12649,189 kg

Kehilangan solid (Solid terikut udara)

$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ =	1%	x	12627,526	=	126,27526
$Al_2(SO_4)_3$ =	1%	x	5,022	=	0,05022
$(NH_4)_2SO_4$ =	1%	x	16,627	=	0,16627
H_2SO_4 =	1%	x	0,0145	=	0,000145

Produk kristal kering solid

Produk solid = solid pada feed - kehilangan solid

$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ =	12627,526	-	126,27526	=	12501,250
$Al_2(SO_4)_3$ =	5,022	-	0,05022	=	4,971
$(NH_4)_2SO_4$ =	16,627	-	0,16627	=	16,461
H_2SO_4 =	0,014	-	0,000145	=	0,0143
Total					**12522,697**

Diharapkan kadar air pada produk akhir = 0,5%
Kadar produk solid = 99,5%

Berat produk solid = 12522,697
Berat total produk solid = 12522,697 / 99,5%
= 12585,625 kg

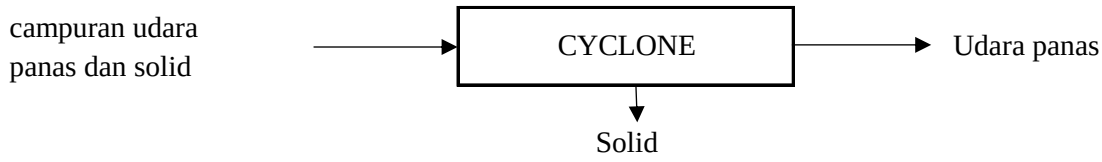
Berat air pada produk = berat total produk solid - berat produk solid
= 12585,625 - 12522,697
= 62,928 kg
Penguapan air = berat air pada feed - berat air pada produk
= 185,132 - 62,928
= 122,204 kg

Neraca Massa

Massa masuk		Massa Keluar	
Komponen	**kg**	**Komponen**	**kg**
Bahan masuk rotary dryer		Produk keluar rotary	
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12627,526	$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12501,250
$Al_2(SO_4)_3$	5,022	$Al_2(SO_4)_3$	4,971
$(NH_4)_2SO_4$	16,627	$(NH_4)_2SO_4$	16,461

H_2O	185,132	H_2O	62,928
H_2SO_4	0,0145	H_2SO_4	0,0143
	12834,320		12585,625
		Campuran uap dan padatan ke cylone	
		$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	126,27526
		$Al_2(SO_4)_3$	0,05022
		$(NH_4)_2SO_4$	0,16627
		$H_2O_{(g)}$	122,20352
		H_2SO_4	0,000145
			248,69541
Total	**12834,320**	**Total**	**12834,320**

9. CYCLONE (H-353)



Kondisi Operasi :

Tekanan = 1 atm

Suhu = 98,25 ^oC (berdasarkan suhu udara panas keluar dari rotary dryer)

Komposisi bahan masuk :

Komposisi	kg
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	126,27526
$Al_2(SO_4)_3$	0,05022
$(NH_4)_2SO_4$	0,16627
$H_2O_{(g)}$	122,20352
H_2SO_4	0,000145
Total	**248,6954**

Asumsi

Effisiensi cyclone = 99% (Ludwig, 1964)

Kehilangan solid = 1% x feed masuk tanpa H2O

= 1% x 126,492

= 1,265 kg

Kehilangan solid sebesar (1%)

$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ =		1%	x	126,27526	=	1,26275
$Al_2(SO_4)_3$	=	1%	x	0,05022	=	0,00050
$(NH_4)_2SO_4$	=	1%	x	0,16627	=	0,00166
H_2SO_4	=	1%	x	0,00014	=	0,0000014
Total						**1,26492**

Produk ke ball mill (99%)

$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ =		99%	x	126,27526	=	125,01250
$Al_2(SO_4)_3$	=	99%	x	0,05022	=	0,04971
$(NH_4)_2SO_4$	=	99%	x	0,16627	=	0,16461
H_2SO_4	=	99%	x	0,00014	=	0,000143
Total						**125,22697**

Neraca Massa

Massa Masuk		**Massa Keluar**	
Komponen	**kg**	**Komponen**	**kg**
Padatan dan uap air masuk		Loss produk ke ball mill	
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	126,27526	$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	125,01250
$Al_2(SO_4)_3$	0,05022	$Al_2(SO_4)_3$	0,04971
$(NH_4)_2SO_4$	0,16627	$(NH_4)_2SO_4$	0,16461
$H_2O_{(g)}$	122,20352	H_2SO_4	0,000143
H_2SO_4	0,000145		125,2270
	248,6954	Debu terikut udara bebas	
		$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	1,26275
		$Al_2(SO_4)_3$	0,00050
		$(NH_4)_2SO_4$	0,00166
		H_2SO_4	0,0000014
		$H_2O_{(g)}$	122,2035
			123,4684
Total	**248,6954**	**Total**	**248,6954**

10. BALL MILL (C-360)

feed masuk total = feed masuk rotary dryer + feed dari cyclone

komposisi	**Rotary Dryer**	**Cyclone**	**Feed Total**	**% Berat**
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12501,2505	125,0125	12626,263	0,9933
$Al_2(SO_4)_3$	4,9713	0,0497	5,0210	0,0004

$(NH_4)_2SO_4$	16,4608	0,1646	16,6254	0,0013
H_2O	62,9281	0	62,9281	0,0050
H_2SO_4	0,0143	0,000143	0,0145	0,000001
Total	**12585,625**	**125,2270**	**12710,85**	**1**

Neraca Massa

Massa Masuk		**Massa Keluar**	
Komponen	**kg**	**Komponen**	**kg**
Produk dari rotary dryer & cyclone		Produk kristal keluar ball	
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12626,2630	$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12626,2630
$Al_2(SO_4)_3$	5,0210	$Al_2(SO_4)_3$	5,0210
$(NH_4)_2SO_4$	16,6254	$(NH_4)_2SO_4$	16,6254
H_2O	62,9281	H_2O	62,9281
H_2SO_4	0,0145	H_2SO_4	0,0145
	12710,8519		12710,8519
Total	**12710,85**	**Total**	**12710,85**

Penentuan kapasitas produksi

Produk Aluminium Amonium Sulfat yang di hasilkan = 12626,263 kg/jam

kapasitas yang diharapkan = 100000 ton/tahun

= 100000000 kg/tahun

= 12626,263 kg/jam

Didapatkan factor scale up dari basis awal 1000 kg/ aluminium sulfat

Factor scale up pabrik = $\frac{12626,263}{12626,263}$

= 1

Yield = $\frac{\text{Massa produk}}{\text{Massa bahan baku awal}}$

0,808755 = $\frac{12626,263}{15607,003}$

= 81%

APPENDIX B
PERHITUNGAN NERACA PANAS

Kapasitas Produksi	=	100000	ton/tahun
	=	100000000	kg/tahun
Waktu Opersi	=	330	hari/tahun
		24	jam
Satuan massa	=	kilogram /jam	
Satuan panas	=	kilokalori/jam	

Persamaan panas untuk kondisi aliran steady ; Q = ΔH = H_2-H_1

Persamaan enthalpi :

H = n.Cp.ΔT = n∫1_Tref^T (Himmelblau,1996)

Dimana :

H	=	Enthalpi	:	kkal
n	=	Mol Bahan	:	kmol
Cp	=	Specific Heat	:	kkal/kmol kelvin
Tref	=	Suhu Refference	:	kelvin
Tref	=	Suhu Bahan	:	kelvin

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

Cp = kkal/kmol ^oK

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

$= n [(A (T - Tref)) + (B/2 (T^2 - Tref^2)) + (C/3 (T^3 - Tref^3))]$

$= \text{kmol} \times \frac{\text{kkal}}{\text{kmol } ^oK} \times {}^oK = \text{kkal}$

Perhitungan integrasi ΔH, (Perry,2008);

Cp = A + B.T + C/T

Cp = kkal/kmol ^oK

$\Delta H = n \int_{Tref}^{T} Cp.\Delta T = n \int_{Tref}^{T} (A + B.T + C/T) dT$

$= n [(A (T - Tref)) + (B/2 (T^2 - Tref^2)) + (C (1/T - 1/Tref))]$

$= \text{kmol} \times \frac{\text{kkal}}{\text{kmol } ^oK} \times {}^oK = \text{kkal}$

Data konstanta heat capacity (A,B,C,D) (kkal/kmol K)

Komponen	BM	A	B	C	Literature
$Al_2(SO_4)_3$	342	63,5			(Perry, 2008)
Al_2O_3	102	24,4			Kopp's Rule
Fe_2O_3	160	24,4			Kopp's Rule
H_2SO_4	98,1	40			Kopp's Rule
$(NH_4)_2SO_4$	132	51,6			(Perry, 2008)
$H_2O_{(l)}$	1 kkal/kg C				(Langes; T 6.3)
$H_2O_{(g)}$	18	8,22			(Perry, 2008)
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	906	335,2			Kopp's Rule

Penentuan Specific heat dengan metode kopp's rule (Himmelblau,1996)

Kontanta metode kopp's rule :

Unsur Solid	Nilai	Unsur Liquid	Nilai
C	1,8	C	2,8
H	2,3	H	4,3
O	4	O	6
S	5,4	S	7,4
P	5,4	P	7,4
F	5	F	7
Si	3,8	Si	5,8
B	2,7	B	4,7
Lainnya	6,2	Lainnya	8

Perhitungan Cp Kopp's untuk $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$

Nilai unsur	Al	:	2	x	6,2	=	12,4
Nilai unsur	S	:	4	x	5,4	=	21,6
Nilai unsur	O	:	40	x	4	=	160
Nilai unsur	N	:	2	x	6,2	=	12,4
Nilai unsur	H	:	56	x	2,3	=	128,8
			Nilai Cp Kopp's			=	335,2

Perhitungan Cp Kopp's Al_2O_3

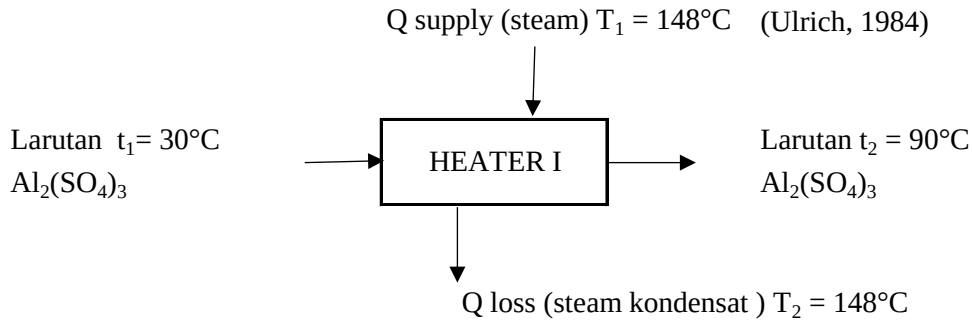
Nilai unsur	Al	:	2	x	6,2	=	12,4
Nilai unsur	O	:	3	x	4	=	12
			Nilai Cp Kopp's			=	24,4

Perhitungan Cp Kopp's Fe_2O_3

Nilai unsur	Fe	:	2	x	6,2	=	12,4
Nilai unsur	O	:	3	x	4	=	12
			Nilai Cp Kopp's			=	24,4

Perhitungan Cp Kopp's	H_2SO_4						
Nilai unsur	H	:	2	x	4,3	=	8,6
Nilai unsur	S	:	1	x	7,4	=	7,4
Nilai unsur	O	:	4	x	6	=	24
			Nilai Cp Kopp's			=	40

1. HEATER - 1 (E-125)



Neraca energi total :

Entalpi bahan masuk + Q supply = Entalpi bahan keluar + Q loss

T saat masuk heater	=	30 ^oC	=	303,15	^oK
T refference	=	25 ^oC	=	298,15	^oK
T saat keluar heater	=	90 ^oC	=	363,15	^oK

ENTHALPI MASUK

1. Entalpi larutan $Al_2(SO_4)_3$ masuk ke heater pada suhu 30^{o}C

Massa bahan masuk :

Komponen	Berat (kg/jam)	BM	kmol/jam
$Al_2(SO_4)_3$	5021,5033	342	14,6828
$H_2O_{(l)}$	12429,4636	18	690,5258
Total	**17450,9668**		

$\Delta H\ Al_2(SO_4)_3 = n \int_{Tref}^{T} Cp.\Delta T$

$= n [(A (T - Tref)) + (B/2 (T^2 - Tref^2)) + (C/3 (T^3 - Tref^3))]$

$= 14,6828 [(63,5 x (303 - 298)]$

$= 14,7 x 317,5$

$= 4661,7757$ kkal/jam

$\Delta H\ H_2O_{(l)} = n \int_{Tref}^{T} Cp.\Delta T$

$= 12429,464 [(1 kkal/kg x (303 - 298)]$

$= 62147,318$ kkal/jam

Entalpi Total (ΔH total) = 66809,094 kkal/jam

2. Q supply

Digunakan steam jenuh dengan suhu 148 °C (Tst) dari steam table diketahui

λ = 2119,5 kj/kg = 506,234 kkal/kg (Smith, 1987)

Q supply = massa steam x λ steam

= 506,234 massa steam kkal/kg

ENTHALPY KELUAR

1. Enthalpy larutan $Al_2(SO_4)_3$ keluar ke heater pada suhu 90°C

Massa bahan keluar :

Komponen	Berat (kg/jam)	BM	kmol/jam
$Al_2(SO_4)_3$	5021,5033	342	14,6828
$H_2O_{(l)}$	12429,4636	18	690,52575
Total	**17450,9668**		

$\Delta H\ Al_2(SO_4)_3 = n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T^2 - $Tref^2$)) + (C/3 (T^3 - $Tref^3$))]

= 14,6828 [(63,5 x (363 - 298)]

= 14,6828 4128

= 60603,084 kkal/jam

$\Delta H\ H_2O_{(l)} = n\int_{Tref}^{T} Cp.\Delta T$

= 12429,4636 [(1 kkal/kg x (363 - 298)]

= 807915,1316 kkal/jam

Entalpi total (ΔH total) = 868518,22 kkal/jam

2. Q losses (panas yang hilang)

Asumsi Q losses = 5% Q supply

= 5% 506,234 massa steam

= 25,3117 massa steam

Neraca energi total

ΔH masuk + Q supply = ΔH keluar + Q losses

66809,0935 + 506,234 m = 868518,22 + 25,3117 m

480,9223 m = 801709,12

massa steam = $\frac{801709,12}{480,9223}$

= 1667,0242 kg /jam

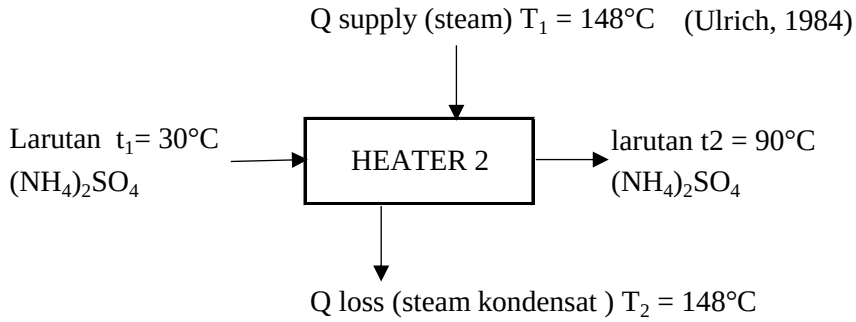
Q supply = massa steam x λ steam
= 1667,0242 x 506,234
= 843904,34 kkal/jam

Q losses = 25,3117 x massa steam
= 25,3117 x 1667,0242
= 42195,217 kkal/jam

Neraca Energi

Massa Masuk		Massa Keluar	
Komponen	**kkal**	**Komponen**	**kkal**
Entalpi masuk heater		Entalpi keluar heater	
ΔH $Al_2(SO_4)_3$	4661,7757	ΔH $Al_2(SO_4)_3$	60603,084
ΔH $H_2O_{(l)}$	62147,318	ΔH $H_2O_{(l)}$	807915,13
Q supply	843904,34	Q losses	42195,217
Total	**910713,43**	**Total**	**910713,43**

2. HEATER - 2 (E-142)



Neraca energi total :

Entalpi bahan masuk + Q supply = Entalpi bahan keluar + Q loss

T saat masuk heater = 30 °C = 303,15 °K

T refference = 25 °C = 298,15 °K

T saat keluar heater = 90 °C = 363,15 °K

ENTHALPI MASUK

1. Entalpi larutan $(NH_4)_2SO_4$ masuk ke heater pada suhu 30°C

Massa bahan masuk :

komponen	Berat (kg/jam)	BM	kmol/jam
$(NH_4)_2SO_4$	2672,5691	132	20,2467
H_2SO_4	0,7229	98,1	0,0074
$H_2O_{(l)}$	3430,6547	18	190,5919
Total	6103,9467		

$\Delta H\ (NH_4)_2SO_4 = n \int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T^2 - $Tref^2$)) + (C/3 (T^3 - $Tref^3$))]
= 20,2467 [(51,6 x (303 - 298)]
= 20,2467 258
= 5223,6577 kkal/jam

$\Delta H\ H_2SO_4 = n \int_{Tref}^{T} Cp.\Delta T$

= 0,0073709 [(40 x (303 - 298)]
= 0,0073709 200
= 1,4741809 kkal/jam

$\Delta H\ H2O\ (l) = n \int_{Tref}^{T} Cp.\Delta T$

= 3430,6547 [(1 kkal/kg x (303 - 298)]
= 17153,273 kkal/jam

Entalpi Total (ΔH total) = 22378,405 kkal/jam

2. Q supply

Digunakan steam jenuh dengan suhu 148 °C (Tst) dari steam table diketahui

λ = 2119,5 kj/kg = 506,234 kkal/kg (Smith,1987)

Q supply = massa steam x λ steam
= 506,234 massa steam kkal/kg

ENYHALPY KELUAR

1. Enthalpy larutan $(NH_4)_2SO_4$ keluar ke heater pada suhu 90°C

Massa bahan keluar :

Komponen	Berat (kg/jam)	BM	kmol/jam
$(NH_4)_2SO_4$	2672,5691	132	20,2467
H_2SO_4	0,7229	98,1	0,0074
$H_2O_{(l)}$	3430,6547	18	190,5919
Total	**6103,9467**		

$\Delta H\ (NH_4)_2SO_4 = n \int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T^2 - $Tref^2$)) + (C/3 (T^3 - $Tref^3$))]
= 20,2467 [(51,6 x (363 - 298)]
= 20,2467 3354
= 67907,551 kkal/jam

$\Delta H\ H_2SO_4$ = $n\int_{Tref}^{T} Cp.\Delta T$

= 0,0074 [(40 x (363 - 298)]
= 0,0074 2600
= 19,1644 kkal/jam

$\Delta H\ H_2O_{(l)}$ = $n\int_{Tref}^{T} Cp.\Delta T$

= 3430,6547 kg/jam [(1 kkal/kg (363 - 298)]
= 222992,55 kkal/jam

Entalpi total (ΔH total) = 290919,27 kkal/jam

2. Q losses (panas yang hilang)

Asumsi Q losses = 5% Q supply
= 5% 506,234 massa steam
= 25,3117 massa steam

Neraca energi total

ΔH masuk + Q supply = ΔH keluar + Q losses

22378,405 + 506,234 m = 290919,27 + 25,3117 m
480,9223 m = 268540,86
massa steam = $\frac{268540,86}{480,9223}$
= 558,38722 kg /jam

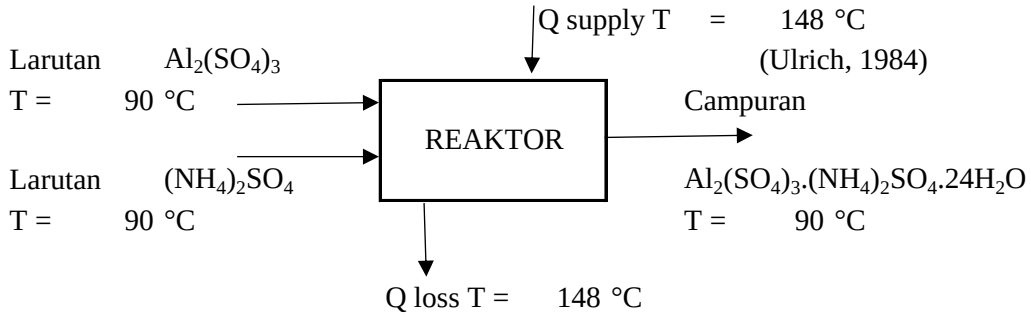
Q supply = massa steam x λ steam
= 558,38722 x 506,234
= 282674,59 kkal/jam

Q losses = 25,3117 x massa steam
= 25,3117 x 558,38722
= 14133,73 kal/jam

Neraca Energi

Massa Masuk		**Massa Keluar**	
Komponen	**kkal**	**Komponen**	**kkal**
Entalpi masuk heater		Entalpi keluar heater	
$\Delta H\ (NH_4)_2SO_4$	5223,6577	$\Delta H\ (NH_4)_2SO_4$	67907,5506
$\Delta H\ H_2SO_4$	1,4742	$\Delta H\ H_2SO_4$	19,1644
$\Delta H\ H_2O_{(l)}$	17153,273	$\Delta H\ H_2O_{(l)}$	222992,555
Q supply	282674,59	Q losses	14133,73
Total	**305053,0**	**Total**	**305053,0**

3. REAKTOR (R-210)



Reaksi yang terjadi (Keyes, 1957)

$$Al_2(SO_4)_3 + (NH_4)_2SO_4 + 24H_2O \longrightarrow Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$$

Neraca energi total :
Entalpi bahan masuk + ΔH reaksi = Entalpi bahan keluar + Q serap

T saat masuk reaktor	=	90	^oC	=	363,15 ^oK
T refference	=	25	^oC	=	298,15 ^oK
T saat keluar reaktor	=	90	^oC	=	363,15 ^oK

Panas Reaksi :
Berdasarkan (Himmelblau , 1996)
Panas reaksi pada suhu 90°C (363.15 K)

$\Delta H_{R363.15\,K}$ = $\Delta H_{R,Tref}$ + (ΔH produk - ΔH reaktan)

ΔH reaktan = Entalpi bahan masuk
ΔH produk = Entalpi bahan keluar
$\Delta H_{R,Tref}$ = Panas reaksi pada suhu refference
Tref = Suhu Reference 25 ^oC = 298,15 ^oK
ΔHR,298.15 = ΔH°f produk - ΔH°f reaktan
ΔH°f = Panas pembentukan bahan

Data ΔH°f komponen

Komponen	ΔH^o_f (kkal/mol)	Literature
$Al_2(SO_4)_3$	-820,99	(Perry,2008)
$(NH_4)_2SO_4$	-281,74	(Perry,2008)
H_2SO_4	-193,69	(Perry,2008)
$H_2O_{(l)}$	-68,317	(Perry,2008)
$H_2O_{(g)}$	-57,798	(Perry,2008)
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	-1419,36	(Perry,2008)

Tinjauan panas reaksi

Dari neraca massa :

mol $Al_2(SO_4)_3$ = 13,9486 kmol = 13948,6202 mol

mol $(NH_4)_2SO_4$ = 13,9486 kmol = 13948,6202 mol

mol $H_2O_{(l)}$ = 334,7669 kmol = 334766,885 mol

mol $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ = 13,9486 kmol = 13948,6202 mol

$\Delta H_{R,298.15K}$ = ΔH°f produk - ΔH°f reaktan

$\Delta H_{R,298.15K}$ = (13948,6202 x -1419,36) - [(13948,6202 x -820,99) + (13948,6202 x -281,74) + (334766,89 x -68,317)]

= -19798114 - -38251831

= 18453717,68 kkal

(Karena nilai (+), maka reaksi berjalan endotermis)

Mencari ΔH reaktan

ΔH $Al_2(SO_4)_3$ = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T^2 - $Tref^2$)) + (C/3 (T^3 - $Tref^3$))]

= 13,9486 x [(63,5 x (363 - 298)]

= 13,9486 x 4127,5

= 57572,93 kkal/jam

ΔH $(NH_4)_2SO_4$ = $n\int_{Tref}^{T} Cp.\Delta T$

= 13,9486 x [(51,6 x (363 - 298)]

= 13,9486 x 3354

= 46783,672 kkal/jam

ΔH $H_2O_{(l)}$ = $n\int_{Tref}^{T} Cp.\Delta T$

= 334,7669 + [(1 kkal/kg (363 - 298)]

= 21759,848 kkal/jam

Total ΔH reaktan = 126116,45 kkal/jam

Mencari ΔH Produk

ΔH $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ = $n\int_{Tref}^{T} Cp.\Delta T$

= 13,94862 x [(335 x (363 - 298)]

= 13,94862 x 21788
= 303912,54 kkal/jam

(ΔHproduk - ΔHreaktan) = 303912,54 - 126116,45
= 177796,0876

$\Delta H_{R368,15K}$ = $\Delta H_{R368,15K}$ + (ΔHproduk - ΔHreaktan)
= 18453717,68 + 177796,0876
= 18631513,77 kkal/jam
(Reaksi bersifat endotermis, membutuhkan panas)

Neraca Energi Total

ΔH masuk +Q supply = ΔH keluar + ΔHReaksi + Q loss
asumsi Q loss = 5% dari Qsupply
(kehilangan maksimum = 10% : Ulrich , 1984)

1181197,3 + Q Supply = 1358993,4 + 18631514 + 5% Qsupply
0,95 Q Supply = 18809310
Q Supply = $\frac{18809310}{0,95}$
Q Supply = 19799274 kkal/jam

Q loss = 19799274 x 5%
= 989963,68 kkal/jam

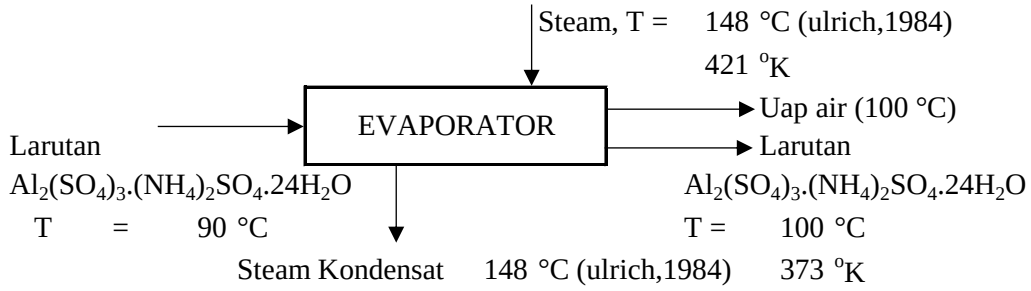
Kebutuhan steam pada suhu 148 °C (ulrich, 1984)
λ steam = 2119,5 kj/kg = 506,234 kkal/kg (Smith, 1987)
Q steam = M steam x λ steam
M steam = $\frac{\text{Q steam}}{\lambda \text{ steam}}$
M steam = $\frac{19799274}{506,234}$
= 39110,912 kg/jam

Neraca Energi

Massa Masuk		Massa Keluar	
Komponen	**kkal**	**Komponen**	**kkal**
Entalpi larutan $Al_2(SO_4)_3$		Entalpi keluar reaktor	
ΔH $Al_2(SO_4)_3$	60603,084	ΔH $Al_2(SO_4)_3$	3030,15421
ΔH $H_2O_{(l)}$	807915,13	ΔH $(NH_4)_2SO_4$	21123,8784
	868518,22	ΔH H_2SO_4	19,1643518
Entalpi larutan $(NH_4)_2SO_4$		ΔH $H_2O_{(l)}$	1030907,69
ΔH $(NH_4)_2SO_4$	67907,551	ΔH $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	303912,537
ΔH H_2SO_4	19,164352		1358993,42

$\Delta H\ H_2O_{(l)}$	222992,55		
	290919,27		
$\Delta H\ H_2O_{(l)}$	21759,848	ΔH Reaksi	18631513,8
Q supply	19799274	Q loss	989963,677
Total	**20980471**	**Total**	**20980470,9**

4. EVAPORATOR (V-320)



1. Produk masuk evaporator suhu 90°C = 363,15 °C

M bahan masuk

Komponen	Berat (kg/jam)	BM	kmol/jam
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12637,4499	906	13,9486
$Al_2(SO_4)_3$	251,0752	342	0,7341
$(NH_4)_2SO_4$	831,3512	132	6,2981
$H_2O_{(l)}$	15860,1183	18	881,1177
H_2SO_4	0,7229	98,1	0,0074
Total	**29580,717**		

Neraca energi total :

Entalpi bahan masuk + Q supply = Entalpi bahan keluar + Q loss

Entalpi bahan masuk :

Entalpi larutan $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ pada suhu = 90 °C

= 363 °K

Neraca energi total :

Entalpi bahan masuk + Q supply = Entalpi bahan keluar + Q loss

$\Delta T = T_S - T_1$

$= 421 - 373$

$= 48\ ^oK$

T_0 = 148 °C = 421,15 °K

T_1 = 100 °C = 373,15 °K

λ_0 = 2119,5 kj/kg 506,56 kkal/kg (Smith,1987)

λ_1 = 2256,9 kj/kg 539,4 kkal/kg (Smith,1987)

D_0 x λ_0 = mf x Cp x (T_1 - T_f) + D_1 x λ_1

D_0 x λ_0 = [(n x Cp)$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$] +
[(n x Cp) $Al_2(SO_4)_3$] + [(n x Cp) $(NH_4)_2SO_4$] +
[(n x Cp) $H_2(SO_4)$] + [(n x Cp) $H_2O_{(l)}$] x
(T_1 - T_f) + D_1 x λ_1

D_0 x 507 = 20907,591 x 75 + D_1 x 539,4

506,56 D_0 = 1568069,3 + 539,4 D_1

D_0 = 3095,5254 + 1,0648294 D_1

D_1 = Massa air menguap
= 6603,5358 kg/jam

D_0 = Massa steam
= 10127,165 kg/jam

Steam ekonomi $\frac{D_1}{D_0} = \frac{6603,5358}{10127,165} = 0,6520617$

Steam ekonomi < 1 , maka digunakan evaporator sebanyak 1 buah

ENTALPI MASUK

1. Entalpi larutan masuk ke evaporator pada suhu 90°C

Hasil perhitungan di tabelkan

Komponen	Berat (kg/j)	BM	kmol/j
$Al_2(SO_4)_3$	251,0752	342	0,7341
$(NH_4)_2SO_4$	831,3512	132	6,2981
$H_2O_{(l)}$	15860,1183	18	881,1177
H_2SO_4	0,7229	98,08	0,0074
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12637,4499	906	13,9486
Total	**29580,717**		

ΔH $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T^2 - $Tref^2$)) + (C/3 (T^3 - $Tref^3$))]
= 13,9486 [(335,2 x (363 - 298)]
= 13,9486 21788
= 303912,54 kkal/jam

ΔH $Al_2(SO_4)_3$ = $n\int_{Tref}^{T} Cp.\Delta T$

= 0,7341 [(63,5 x (363 - 298)]
= 0,7341 4127,5
= 3030,1542 kkal/jam

$\Delta H\ H_2O_{(l)}$ = $n\int_{Tref}^{T} Cp.\Delta T$

= 15860,1183 kg/jan [(1 kkal/kg (363 - 298)]
= 1030907,7 kkal/jam

$\Delta H\ (NH_4)_2SO_4$ = $n\int_{Tref}^{T} Cp.\Delta T$

= 6,2981 [(51,6 x (363 - 298)]
= 6,2981 3354
= 21123,8784 kkal/jam

$\Delta H\ H_2SO_4$ = $n\int_{Tref}^{T} Cp.\Delta T$

= 0,0074 [(40 x (363 - 298)]
= 0,0074 2600
= 19,1644 kkal/jam

Entalpi total (ΔH Total) = 1358993,421 kkal/jam

ENTHALPI KELUAR

1. Produk keluar dari evaporator suhu 100°C = 373 °K

Massa bahan keluar

Komponen	Berat (kg/j)	BM	kmol/j
$Al_2(SO_4)_3$	251,07516	342	0,7341379
$(NH_4)_2SO_4$	831,35121	132	6,2981152
$H_2O_{(l)}$	9256,5824	18	514,25458
H_2SO_4	0,7229383	98,1	0,0073709
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12637,45	906	13,94862
Total	22977,182		

$\Delta H\ \ Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$ = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 13,94862 [(335,2 x (373 - 298)
= 13,94862 25140
= 350668,31 kkal/jam

Al2(SO4)3 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,7341379 [(63,5 x (373 - 298)
= 0,7341379 4762,5

= 3496,3318 kkal/jam

ΔH H2O (l) = $n\int_{Tref}^{T} Cp.\Delta T$

= 9256,5824 kg/jam 1 kkal/kg x (373 - 298)
= 694243,68 kkal/jam

ΔH (NH4)2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 6,2981152 [(51,6 x (373 - 298)
= 6,2981152 3870
= 24373,706 kkal/jam

ΔH H2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,0073709 [(40 x (373 - 298)
= 0,0073709 3000
= 22,112714 kkal/jam

Entalpi total (ΔH Total) = 1072804,1 kkal/jam

2. Entalpi uap air ke udara bebas pada suhu 100°C = 373 K

ΔH = $\int_{Tref}^{T} Cp.\Delta T$ + n λ (terjadi perubahan fase)

massa uap air = 6603,5358 kg = 367 kmol

ΔH H2O = $\int_{Tref}^{T} Cp.\Delta T$ = [(A(T-Tref))+(B/2 (T^2-Tref^2))-(C(1/T-1/Tref)]
= (8,22 x (373 - 298)
= 8,22 x 75
= 617 kkal/kmol

λ H2O = 17465,4 kkal/kmol (Mc Cabe , 1993)

ΔH = $\int_{Tref}^{T} Cp.\Delta T$ + n λ

ΔH H2O uap = (367 x 617) + (367 x 17465,4
= 6633581,9 kkal/jam

total entalpi bahan keluar = 1072804,1 + 6633581,9
= 7706386 kkal/jam

Neraca Energi Total

ΔH masuk + Q supply = ΔH keluar + Q loss

asumsi Q loss = 5% dari Qsupply (kehilangan maksimum = 10% : Ulrich , 1984)

1358993,4 + Q Supply = 7706386 + 5% Q supply

0,95 Q Supply = 6347392,6

$$Q\ Supply = \frac{6347392,6}{0,95}$$

Q Supply = 6681465,9 kkal/jam

Q Loss = 6681465,9 x 5%

= 334073,3 kkal/jam

kebutuhan steam pada suhu 148 °C (ulrich, 1984)

λ steam = 2119,5 kj/kg = 506,234 kkal/kg (smith, 1987)

Q steam = M steam x λ steam

$$M\ steam = \frac{Q\ steam}{\lambda\ steam}$$

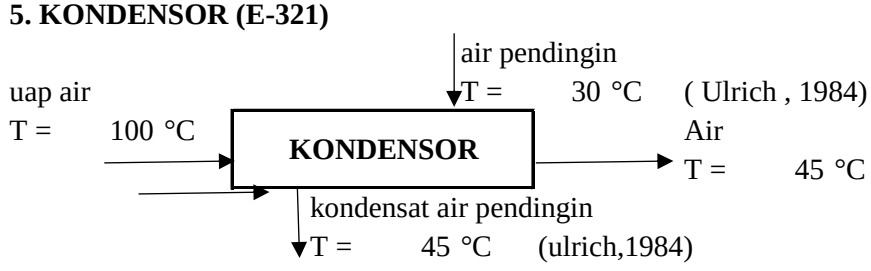
$$M\ steam = \frac{6681465,9}{506,234}$$

= 13198,374 kg/jam

Neraca Energi

Massa masuk		Massa keluar	
Komponen	**kkal**	**Komponen**	**kkal**
Entalpi masuk evaporator		Entalpi keluar evaporator	
ΔH $Al_2(SO_4)_3$	3030,1542	ΔH $Al_2(SO_4)_3$	3496,33178
ΔH $(NH_4)_2SO_4$	21123,878	ΔH $(NH_4)_2SO_4$	24373,7058
ΔH H_2SO_4	19,164352	ΔH H_2SO_4	22,1127136
ΔH $H_2O_{(l)}$	1030907,7	ΔH $H_2O_{(l)}$	694243,683
ΔH $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	303912,54	ΔH $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	350668,312
	1358993,4		1072804,15
		ΔH $H_2O_{(g)}$	6633581,9
Q Supply	6681465,9	Q Loss	334073,296
Total	**8040459,3**	**Total**	**8040459,34**

5. KONDENSOR (E-321)



kondisi operasi:
tekanan operasi = 26 inHg = 0,13 atm (badger,1955)
suhu operasi = 45 °C (suhu kondensasi)
neraca energi total :
Entalpi bahan masuk = Entalpi bahan keluar + Q serap

ENTHALPI MASUK

1. Entalpi Uap air yang keluar evaporator pada suhu 100°C = 373 K
panas masukdari evaporator ΔH1 = 6633581,9 kkal/jam

ENTHALPI KELUAR

Asumsi : Non Condansable gas tidak boleh melebihi 1% dari uap air yang masuk
asumsi uap air yang lolos (non-condensable gas) = 1% dari yang masuk
H2O uap = 1% x 6603,5358 (Ludwig: 375)
= 65,375 kg
kondensat = feed masuk - uap yang lolos
H2O liquid = 6603,5358 - 65,375
= 6538,161 kg

1. Enthalpi uap ke udara pada suhu 45 °C

massa uap

komponen	Berat (kg/j)	BM	Kmol/j
H2O (g)	65,375	18	3,6319447
total	65,375		

Data kapasitas panas dan panas laten pada suhu 45 °C = 318 K

Cp = $\int_{Tref}^{T} Cp.\Delta T$ = [(A(T-Tref))+(B/2 (T^2-Tref^2))-(C(1/T-1/Tref)]
= (8,22 x (318 - 298)
= 8,22 x 20
= 164 kkal/kmol

Entalpi bahan :
ΔH H2O = 3,6319447 x 164
= 597,09171 kkal/jam

2. Entalpi konsensat ke penampung pada suhu 45 °C

massa kondensat

komponen	Berat (kg/j)	BM	Kmol/j
H2O	6538,161	18	363,23116
total	6538,161		

λ air pendingin = 1026,63 kkal/kg (smith,1987)
Data kapasitas panas dan panas laten pada suhu 45 °C 318 K

Komponen	n.Cp.ΔT (kkal)	n λ (kkal)	ΔH=n.Cp.ΔT+n.λ(kkal)
H2O	130763,2161	372904,0014	503667,2174

-

ΔH keluar = 597,09171 + 503667,22
= 504264,31 kkal/jam

Neraca Energi total

Asumsi Q loss = 5% ΔH masuk

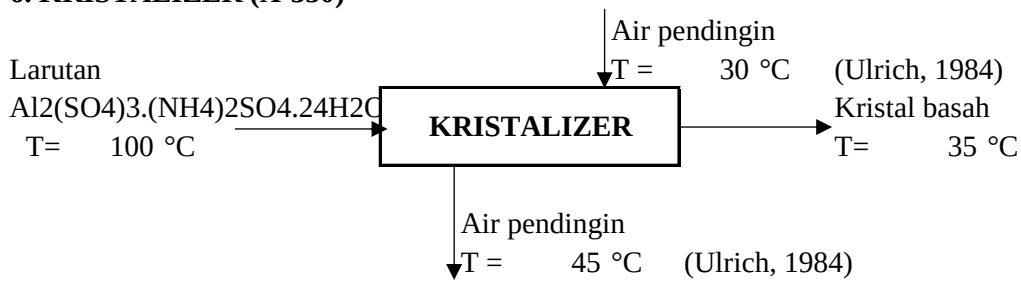
ΔH masuk = ΔH keluar + Q serap + Q loss
6633581,9 = 504264,31 + Q serap + 331679,09
Q serap = 5797638,5
Q loss = 331679,09

kebutuhan air pendingin (m) = $\frac{Q}{Cp \times \Delta T}$
= 386509,23 kg/jam

Neraca Energi

Massa Masuk		Massa Keluar	
Komponen	**kkal**	**Komponen**	**kkal**
Uap dari evaporator		H_2O keluar ke kondensor	
ΔH $H_2O_{(g)}$	6633581,9	Kondensat	597,09171
		$H_2O_{(l)}$	503667,22
		Q Loss	331679,09
		Q Terserap	5797638,5
Total	**6633581,9**	**Total**	**6633581,9**

6. KRISTALIZER (X-330)



ENTALPI MASUK

1. Produk masuk ke kristalizer pada suhu 100°C 373 K

Massa bahan masuk

Komponen	Berat (kg/j)	BM	kmol/j
Al2(SO4)3	251,07516	342	0,7341379
(NH4)2SO4	831,35121	132	6,2981152
H2O(l)	9256,5824	18	514,25458
H2SO4	0,7229383	98,08	0,0073709
Al2(SO4)3.(NH4)2SO4.24H2O	12637,45	906	13,94862
Total	22977,182		

ΔH Al2(SO4)3.(NH4)2SO4.24H2O = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 13,94862 [(335,2 x (373 - 298)
= 13,94862 25140
= 350668,31 kkal/jam

Al2(SO4)3 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,7341379 [(63,5 x (373 - 298)
= 0,7341379 4762,5
= 3496,3318 kkal/jam

ΔH H2O (l) = $n\int_{Tref}^{T} Cp.\Delta T$

= 9256,5824 kg/jan 1 kkal/kg x (373 - 298)
= 694243,68 kkal/jam

ΔH (NH4)2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 6,2981152 [(51,6 x (373 - 298)
= 6,2981152 3870
= 24373,706 kkal/jam

ΔH H2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,0073709 [(40 x (373 - 298)
= 0,0073709 3000
= 22,112714 kkal/jam

Entalpi total (ΔH Total) = 1072804,146 kkal/jam

2. Air pendingin masuk pada suhu 30 °C
massa air pendingin masuk = m kg
Cp air = 1 kkal/kg C (Perry, 2008)
ΔH air pendingin = m x Cp x ΔT
= m x 1 x (30 - 25)
= 5 m
Total ΔH masuk kristaliz = 1072804,1 + 5m

ENTHALPI KELUAR

1. Produk keluar dari kristalizer pada suhu 35° = 308 K

massa bahan keluatr

Komponen	Berat (kg/j)	BM	kmol/j
Al2(SO4)3	251,07516	342	0,7341379
(NH4)2SO4	831,35121	132	6,2981152
H2O(l)	9256,5824	18	514,25458
H2SO4	0,7229383	98,1	0,0073709
Al2(SO4)3.(NH4)2SO4.24H2O	12637,45	906	13,94862
Total	22977,182		

ΔH Al2(SO4)3.(NH4)2SO4.24H2O = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 13,94862 [(335,2 x (308 - 298)
= 13,94862 3352
= 46755,775 kkal/jam

Al2(SO4)3 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,7341379 [(63,5 x (308 - 298)
= 0,7341379 635
= 466,17757 kkal/jam

ΔH H2O (l) = $n\int_{Tref}^{T} Cp.\Delta T$

= 9256,5824 kg/jam 1 kkal/kg x (308 - 298)
= 92565,824 kkal/jam

ΔH (NH4)2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 6,2981152 [(51,6 x (308 - 298)
= 6,2981152 516
= 3249,8274 kkal/jam

ΔH H2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,0073709 [(40 x (308 - 298)
= 0,0073709 400
= 2,9483618 kkal/jam

Entalpi total (ΔH Total) = 143040,55 kkal/jam

2. Air pendingin masuk pada suhu 45 °C
massa air pendingin masuk = m kg
Cp air = 1 kkal/kg C (Perry, 2008)
ΔH air pendingin = m x Cp x ΔT
= m x 1 x (45 - 25)
= 20 m

Neraca Energi Total :
ΔH masuk + ΔH Pendingin = ΔH keluar + ΔH terserap
1072804,1 + 5 m = 143040,55 + 20 m
15 m = 929763,59
m = 61984,24 kg
ΔH Pendingin = 5 m
= 5 x 61984,24
= 309921,2 kkal
ΔH Pendingin keluar = 20 m
= 20 x 61984,24
= 1239684,8 kkal

Neraca Energi

Massa Masuk		**Massa Keluar**	
Komponen	**kkal**	**Komponen**	**kkal**
Entalpi masuk kristalizer		Entalpi keluar evaporator	
ΔH $Al_2(SO_4)_3$	3496,3318	ΔH $Al_2(SO_4)_3$	466,177571
ΔH $(NH_4)_2SO_4$	24373,706	ΔH $(NH_4)_2SO_4$	3249,82744
ΔH H_2SO_4	22,112714	ΔH H_2SO_4	2,94836181
ΔH $H_2O_{(l)}$	694243,68	ΔH $H_2O_{(l)}$	92565,8244
ΔH $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	350668,31	ΔH $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	46755,775
	1072804,1		143040,553
ΔH Pendingin	309921,2	ΔH Terserap	1239684,79
Total	**1382725,3**	**Total**	**1382725,34**

7. ROTARY DRYER (B-350)

kristal basah
T = 35 °C

kristal kering
T = 105 °C

udara panas keluar
T = 98,25 °C

Udara panas masuk
T = 120 °C
(berdasarkan suhu udara panas masuk)

Kadar air masuk Rotary Dryer = 1,44% (perhitungan neraca massa)
Kadar air keluar Rotary Dryer = 0,5 % (perhitungan neraca massa)
suhu bahan masuk (t1) = 35 °C
suhu bahan keluar (t2) = 105 °C
suhu udara masuk (tg1) = 120 °C (berdasarkan suhu udara panas masuk)

Menentukan Wet Bulb Temperatur

suhu udara masuk (tg1) = 120 °C
Relative Humidity = 60%
Humidity udara masuk (WG) 35 C = 0,021 kg H2O/kg udara kering (Geankoplis,1997)

Menghitung suhu wet bulb udara masuk pada 120 °C
pers.(Badger,1955)

$$Ww-Wg = \frac{hg}{29 \times \lambda \times Kg \times P}(tg-tw)$$

Dengan :
Ww = humidity udara pada suhu tw kg air/ kg udara kering
Wg = humidity udara pada suhu tg kg air/ kg udara kering
hg = heat tranfer coefficient dari udara ke permukaan basah
tg = suhu udara panas masuk dryer = 120 °C 248 F
tw = suhu wet bulb = 92 °C (trial) 198 F
Kg = mass transfer coefficient dari permukaan basah ke udara
P = tekanan operasi
λ = panas laten udara basah (smith,1987)

dari (Badger, 1955) diketahui : $\frac{hg}{29 \times \lambda \times Kg \times P} = 0,26$

trial 1
suhu wet bulb (tw) = 90 °C
panas laten pada 90 C = 2283,2 kj/kg (smith,1987)
Humidity pada 90 C = 0,023 kg air/kg udara kering (Himmeblau,1996)

$$Ww-Wg = \frac{hg}{29 \times \lambda \times Kg \times P}(tg-tw)$$

$$0,02 - 0,02 = \frac{0,26}{2283,2} 120 - 90$$

0,002 = 0,003
tw terlalu rendah

trial 2
suhu wet bulb (tw) = 92 °C
panas laten pada 92 C = 2278 kj/kg (smith,1987)
Humidity pada 92 C = 0,024 kg air/kg udara kering (Himmeblau,1996)

$$Ww - Wg = \frac{hg}{29 \times \lambda \times Kg \times P}(tg - tw)$$

$$0{,}02 - 0{,}02 = \frac{0{,}26}{2278}\ 120 - 92$$

$$0{,}003 = 0{,}003 \quad \text{(asumsi tw bener)}$$

jadi suhu wet bulb(tw) pada 120 C adalah 92 C

perhitungan suhu udara panas keluar ke dryer (tg2) :

$$NTU = \ln\left(\frac{(tg1 - tw)}{(tg2 - tw)}\right)$$

dengan : tg1 = suhu udara masuk (°F)
tg2 = suhu udara keluar (°F)
NTU = total number of transfer unit (1.5 s/d 2) (Badger,1955)
ditetapkan = 1,5

maka

$$1{,}5 = \ln\left(\frac{248 - 198}{tg2 - 198}\right)$$

$$4{,}4816 = \frac{248 - 198}{tg2 - 198}$$

$$tg2 = 208{,}85\ °F$$

$$= 98{,}25\ °C$$

Neraca Energi Total :

ΔH bahan masuk + ΔH udara masuk = ΔH bahan keluar + ΔH udara keluar

ENTHALPI MASUK

1. Produk masuk ke Rotary dryer pada su 35 °C = 308 K

massa bahan masuk

Komponen	Berat (kg/j)	BM	kmol/j
Al2(SO4)3	5,0215033	342	0,0146828
(NH4)2SO4	16,627024	132	0,1259623
H2O(l)	185,13165	18	10,285092
H2SO4	0,0144588	98,08	0,0001474
Al2(SO4)3.(NH4)2SO4.24H2O	12627,526	906	13,937666
total	12834,32		

$$\Delta H \quad Al2(SO4)3.(NH4)2SO4.24H2O = n\int_{Tref}^{T} Cp.\Delta T$$

$$= n\,[\,(A\,(T - Tref)) + (B/2\,(T2 - Tref2)) + (C/3\,(T3 - Tref3))\,]$$

$$= 13{,}937666\ [(\ 335{,}2\ x\ (\ 308\ -\ 298\ )$$

$$= 13{,}937666\ \ 3352$$

$$= 46719{,}058\ \text{kkal/jam}$$

ΔH Al2(SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,0146828 [(63,5 x (308 - 298)
= 0,0146828 635
= 9,3235514 kkal/jam

ΔH H2O (l) = $n\int_{Tref}^{T} Cp.\Delta T$

= 185,13165 kg/jan 1 kkal/kg x (308 - 298)
= 1851,3165 kkal/jam

ΔH (NH4)2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,1259623 [(51,6 x (308 - 298)
= 0,1259623 516
= 64,996549 kkal/jam

ΔH H2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,0001474 [(40 x (308 - 298)
= 0,0001474 400
= 0,0589672 kkal/jam

Entalpi total (ΔH Total) = 48644,75331 kkal/jam

ENTHALPI KELUAR

1. Produk keluar dari rotary dryer pada suhu 1 = 378 K

hasil perhitungan ditabelkan

Komponen	Berat (kg/j)	BM	kmol/j
Al2(SO4)3	4,9712882	342	0,0145359
(NH4)2SO4	16,460754	132	0,1247027
H2O(l)	62,928125	18	3,4960069
H2SO4	0,0143142	98,1	0,0001459
Al2(SO4)3.(NH4)2SO4.24H2O	12501,25	906	13,79829
Total	12585,625		

ΔH Al2(SO4)3.(NH4)2SO4.24H2O = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 13,79829 [(335,2 x (378 - 298)

= 13,79829 26816
= 370014,94 kkal/jam

ΔH Al2(SO4 = $n\int_{Tref}^{T} Cp.\Delta T$
= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,0145359 [(63,5 x (378 - 298)
= 0,0145359 5080
= 73,842527 kkal/jam

ΔH H2O (l) = $n\int_{Tref}^{T} Cp.\Delta T$
= 62,928125 kg/jan 1 kkal/kg x (378 - 298)
= 5034,25 kkal/jam

ΔH (NH4)2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$
= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,1247027 [(51,6 x (378 - 298)
= 0,1247027 4128
= 514,77267 kkal/jam

ΔH H2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$
= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,0001459 [(40 x (378 - 298)
= 0,0001459 3200
= 0,4670205 kkal/jam

Entalpi total (ΔH Total) = 375638,27 kkal/jam

2. Produk keluar dari Cyclone pada suhu 98,25 = 371 K
hasil perhitungan ditabelkan (tanpa uap air H2O)

Komponen	Berat (kg/j)	BM	kmol/j
Al2(SO4)3	0,050215	342	0,0001468
(NH4)2SO4	0,1662702	132	0,0012596
H2SO4	0,0001446	98,1	1,474E-06
Al2(SO4)3.(NH4)2SO4.24H2O	126,27526	906	0,1393767
Total	126,49189		

ΔH Al2(SO4)3.(NH4)2SO4.24H2O = $n\int_{Tref}^{T} Cp.\Delta T$
= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,1393767 [(335,2 x (371 - 298)

= 0,1393767 24553,4
= 3422,171 kkal/jam

ΔH Al2(SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,0001468 [(63,5 x (371 - 298)
= 0,0001468 4651,375
= 0,6829501 kkal/jam

ΔH (NH4)2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,0012596 [(51,6 x (371 - 298)
= 0,0012596 3779,7
= 4,7609972 kkal/jam

ΔH H2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 1,474E-06 [(40 x (371 - 298)
= 1,474E-06 2930
= 0,0043194 kkal/jam

Entalpi total (ΔH Total) = 3427,6192 kkal/jam

3. Perhitungan untuk uap H2O

H = $\int_{Tref}^{T} Cp.\Delta T$ + n λ erubahan fase)

massa uap air = 122,2035 kg = 6,79 kmol

$\int_{Tref}^{T} Cp.\Delta T$ H2O(g) = [(A(T-Tref))+(B/2(T^2-Tref^2))+(C/3(T^3-Tref^3))]
= [(8,22 x (371 - 298)
= 602,115 kkal/kmol

λ H2C = 981,62 x 18
λ H2C = 17669,16 kkal/kmol (Mc Cabe , 1993)

Entalpi Baha H = $n\int_{Tref}^{T} Cp.\Delta T$+ n λ

H H2O uap = (6,79 x 602) + (6,79 x 17669,16
= 124045,23 kkal/jam

total Entalpi bahan keluar = 375638,27 + 3427,6192 + 124045,233
= 503111,12

Neraca energi total :

ΔH bahan masuk + ΔH udara masuk = ΔH bahan keluar + ΔH udara keluar
48644,753 + ΔH udara masuk = 503111,12 + ΔH udara keluar

suhu udara masuk(tg1) = 120 °C
Cp udara pada suhu 120°C = 0,264 kkal/kg °C (kern,1988)
udara = Cp x ΔT
= 0,26 x (120 - 25)
= 25,08 kkal/kg = 726,342 kkal/mol

suhu udara masuk(tg2) = 98,25 °C
Cp udara pada suhu 98,25°C = 0,245 kkal/kg °C (kern,1988)
udara = Cp x ΔT
= 0,25 x (98,2 - 25)
= 17,946 kkal/kg = 519,726 kkal/mol

ΔH bahan masuk + ΔH udara masuk = ΔH bahan keluar + ΔH udara keluar
48644,753 + ΔH udara masuk = 503111,12 + ΔH udara keluar
48644,753 + (n $\int_{Tref}^{T} Cp\ \Delta T$) udara masuk = 503111,12 + (n$\int_{Tref}^{T} Cp\ \Delta T$) udara keluar

48644,753 + 726,342 n = 503111,12 + 519,7 n
206,616 n = 454466,37 kkal
n udara = 2199,5662 kmol/jam

BM udara = 28,961 kg/kmol
Berat udara = 2199,5662 x 28,961
= 63701,636 kg

Perhitungan entalpi udara:

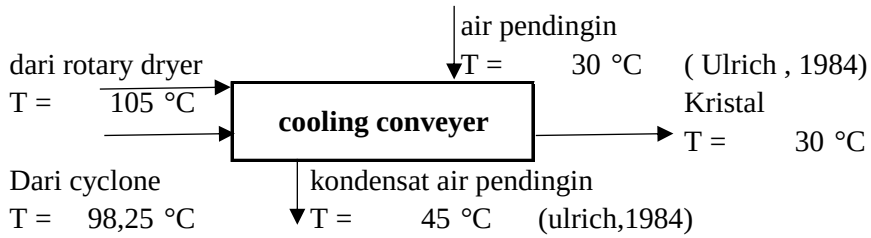
Entalpi udara masuk :
Cp.ΔT udara, 120° = 726,342 kkal/mol
mol udara = 2199,5662 kmol
ΔH udara masuk = 726,342 x 2199,5662
= 1597637 kkal/jam

Entalpi udara keluar :
Cp.ΔTudara, 98.25 = 519,726 kkal/mol
mol udara = 2199,5662 kmol
ΔH udara keluar = 519,726 x 2199,5662
= 1143170,7 kkal/jam

Neraca Energi

Massa Masuk		Massa Keluar	
Komponen	**kkal**	**Komponen**	**kkal**
Entalpi masuk rotary dryer		Entalpi keluar rotary dryer	
ΔH $Al_2(SO_4)_3$	9,3235514	ΔH $Al_2(SO_4)_3$	73,8425272
ΔH $(NH_4)_2SO_4$	64,996549	ΔH $(NH_4)_2SO_4$	514,772667
ΔH H_2SO_4	0,0589672	ΔH H_2SO_4	0,46702051
ΔH $H_2O_{(l)}$	1851,3165	ΔH $H_2O_{(l)}$	5034,24999
ΔH $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	46719,058	ΔH $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	370014,937
	48644,753		375638,27
		Entalpi ke cylone	
		ΔH $Al_2(SO_4)_3$	0,68295014
		ΔH $(NH_4)_2SO_4$	4,7609972
		ΔH H_2SO_4	0,00431935
		ΔH $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	3422,17098
		ΔH $H_2O_{(l)}$	124045,233
			127472,852
Udara panas	1597637	Udara keluar	1143170,66
Total	**1646281,8**	**Total**	**1646281,78**

8. COOLING CONVEYOR (J-354)



ENTHALPI MASUK

1. Produk dari Rotary dryer 105 °C = 378 K

massa bahan masuk

Komponen	Berat (kg/j)	BM	kmol/j
Al2(SO4)3	4,9712882	342	0,0145359
(NH4)2SO4	16,460754	132	0,1247027
H2O(l)	62,928125	18	3,4960069
H2SO4	0,0143142	98,08	0,0001459
Al2(SO4)3.(NH4)2SO4.24H2O	12501,25	906	13,79829
total	12585,625		

$$\Delta H \quad Al2(SO4)3.(NH4)2SO4.24H2O = n \int_{Tref}^{T} Cp.\Delta T$$

$$= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]$$

= 13,79829 [(335,2 x (378 - 298)
= 13,79829 26816
= 370014,94 kkal/jam

ΔH Al2(SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,0145359 [(63,5 x (378 - 298)
= 0,0145359 5080
= 73,842527 kkal/jam

ΔH H2O (l) = $n\int_{Tref}^{T} Cp.\Delta T$

= 62,928125 kg/jam 1 kkal/kg x (378 - 298)
= 5034,25 kkal/jam

ΔH (NH4)2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,1247027 [(51,6 x (378 - 298)
= 0,1247027 4128
= 514,77267 kkal/jam

ΔH H2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,0001459 [(40 x (378 - 298)
= 0,0001459 3200
= 0,4670205 kkal/jam

Entalpi total (ΔH Total) = 375638,2696 kkal/jam

2. Produk dari Cyclone 98,25 °C = 371 K

massa bahan masuk

Komponen	Berat (kg/j)	BM	kmol/j
Al2(SO4)3	0,0497129	342	0,0001454
(NH4)2SO4	0,1646075	132	0,001247
H2SO4	0,0001431	98,08	1,459E-06
Al2(SO4)3.(NH4)2SO4.24H2O	125,0125	906	0,1379829
total	125,22697		

ΔH Al2(SO4)3.(NH4)2SO4.24H2O = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,1379829 [(335,2 x (371 - 298)
= 0,1379829 24552,652
= 3387,8461 kkal/jam

ΔH Al2(SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,0001454 [(63,5 x (371 - 298)
= 0,0001454 4651,2333
= 0,6761 kkal/jam

ΔH (NH4)2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,001247 [(51,6 x (371 - 298)
= 0,001247 3779,5849
= 4,7132437 kkal/jam

ΔH H2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 1,459E-06 [(40 x (371 - 298)
= 1,459E-06 2929,9107
= 0,004276 kkal/jam

Entalpi total (ΔH Total) = 3393,2397 kkal/jam

Total entalpi masuk = 379031,51 kkal/jam

ENTHALPI KELUAR

1. Produk kristal keluar cooling conveyer 30 °C = 303 K

massa bahan masuk

Komponen	Berat (kg/j)	BM	kmol/j
Al2(SO4)3	5,0210011	342	0,0146813
(NH4)2SO4	16,625361	132	0,1259497
H2O(l)	62,928125	18	3,4960069
H2SO4	0,0144573	98,08	0,0001474
Al2(SO4)3.(NH4)2SO4.24H2O	12626,263	906	13,936273
Total	12710,852		

ΔH Al2(SO4)3.(NH4)2SO4.24H2O = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 13,936273 [(335,2 x (303 - 298)
= 13,936273 1676

= 23357,193 kkal/jam

ΔH Al2(SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,0146813 [(63,5 x (303 - 298)
= 0,0146813 317,5
= 4,6613095 kkal/jam

ΔH H2O (l) = $n\int_{Tref}^{T} Cp.\Delta T$

= 62,928125 kg/jam 1 kkal/kg x (303 - 298)
= 314,64062 kkal/jam

ΔH (NH4)2SO4 = n $\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,1259497 [(51,6 x (303 - 298)
= 0,1259497 258
= 32,495025 kkal/jam

ΔH H2SO4 = $n\int_{Tref}^{T} Cp.\Delta T$

= n [(A (T - Tref)) + (B/2 (T2 - Tref2)) + (C/3 (T3 - Tref3))]
= 0,0001474 [(40 x (303 - 298)
= 0,0001474 200
= 0,0294807 kkal/jam

Entalpi total (ΔH Total) = 23709,01936 kkal/jam

Neraca Energi total

Δhmasuk = ΔH keluar + Q serap
379031,51 = 23709,019 + Q serap
Q serap = 355322,49

kebutuhan air pendingin (m) = $\frac{Q}{Cp \times \Delta T}$

= 23688,166 kg/jam

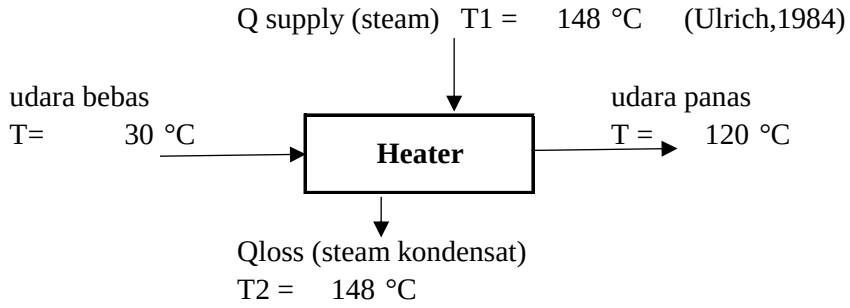
Neraca Energi

Massa Masuk		Massa Keluar	
Komponen	**kkal**	**Komponen**	**kkal**
Entalpi masuk		Entalpi keluar	
ΔH $Al_2(SO_4)_3$	74,518627	ΔH $Al_2(SO_4)_3$	4,66130953

ΔH $(NH_4)_2SO_4$	519,48591	ΔH $(NH_4)_2SO_4$	32,4950246
ΔH H_2SO_4	0,4712965	ΔH H_2SO_4	0,02948067
ΔH $H_2O_{(l)}$	5034,25	ΔH $H_2O_{(l)}$	314,640624
ΔH $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	373402,78	ΔH $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	23357,1929
	379031,51		23709,0194
		ΔH Terserap	355322,49
Total	**379031,51**	**Total**	**379031,5**

9. HEATER- 3 (E-352)

fungsi : memanaskan udara menjadi udara panas pada suhu 120°C pada rotary dryer



Neraca Energi Total :

Entalpi bahan masuk + Q supply = Entalpi bahan keluar + Q loss

T saat masuk heater = 30 °C = 303,15 K

T refference = 25 °C = 298,15 K

T saat keluar heater = 120 °C = 393,15 K

Entalpi udara masuk :

mol udara = 2199,5662 kmol (perhitungan dryer)

ΔH Udara masuk = 519,726 x 2199,5662

= 1143170,7 kkal

Entalpi keluar

berdasarkan perhitungan rotary dryer, entalpi udara panas = 1597637 kkal

Neraca energi total :

Entalpi bahan masuk + Q supply = Entalpi bahan keluar + Q loss

kehilangan maksimum = 5% (ulrich.1984)

Asumsi Q loss = 5% Q supply

1143170,7 + Q supply = 1597637 + 5% Q supply

95% Q supply = 454466,37 kkal

Q supply = 478385,65 kkal

Q loss = 5% Q supply
= 5% x 478385,65
= 23919,283 kkal

kebutuhan steam :
kebutuhan steam pada tekanan 4.5 atm dan suhu steam 148°C (Ulrich,1984)
λ steam = 2119,5 kj/kg = 506,234 kkal/kg (Smith,1987)
Q steam = M steam λ steam

$$\text{M steam} = \frac{\text{Q steam}}{\lambda \text{ steam}}$$

$$= \frac{478385,65}{506,234}$$

= 944,98918 kg

Neraca Energi

Massa Masuk		Massa Keluar	
Komponen	**kkal**	**Komponen**	**kkal**
Entalpi udara bebas		Entalpi udara panas ke rotary dryer	
ΔH Udara masuk	1143170,7	ΔH Udara keluar	1597637,02
Q supply	478385,65	Q loss	23919,2826
Total	**1621556,3**	**Total**	**1621556,3**

APPENDIX C
PERHITUNGAN SPESIFIKASI PERALAT

Kapasitas Produksi = 100000 ton/tahun
= 100000000 kg/tahun
Waktu Opersi = 330 hari/tahun
24 jam
Satuan massa = kilogram /jam
Satuan panas = kilokalori/jam

1. GUDANG ALUMINIUM SULFAT (F-110)

Fungsi : Untuk menyimpan Al_2SO_4 untuk sementara waktu sebelum diperoses

Type : Bangunan beratap asbes, berdinding asbes dengan kerangka besi dan lantai semen cor

Bahan masuk :

Komponen	Berat	Fraksi Berat	ρ (gr/cm)
$Al_2(SO_4)_3$	5285,792926	0,7651	2,67
Al_2O_3	1576,480313	0,2282	3,99
Fe_2O_3	46,35690829	0,0067	5,25
Total	6908,630147	1	

Perhitungan :

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ komponen}} \times 1 \text{ gr/cc}} \times 1 \text{ gr/cc}$$

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0,7651}{2,67} + \frac{0,22819}{3,99} + \frac{0,0067}{5,25}} \times 62,43$$

$$= 180,9445225 \text{ lb/cuft}$$

Rate Massa = 6908,630147 kg/jam

= 15233,52947 lb/jam

ρ campuran = ρ bahan

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

$$= \frac{15233,52947 \text{ lb/jam}}{180,9445225 \text{ lb/cuft}}$$

$$= 84,189 \text{ cuft/jam}$$

Ditentukan :

waktu tinggal	=	30	hari
Tinggi	=	x	m
Panjang	=	3x	m
Lebar	=	3x	m

Volume bahan = 84,189 cuft/jam

= 84,189 x 24 x 30

= 60616,04448 cuft

Volume gudang (80% volume bahan) $= \frac{\text{Volume bahan}}{0,8}$

$= \frac{60616,04448}{0,8}$

= 75770,0556 cuft

= 2144,29257 m^3

Volume gudang = p x l x t

2144,2926 = 3x x 3x x x

2144,2926 = $9x^3$

$\frac{2144,2926}{9} = x^3$

x^3 = 238,255

x = 6,1994

p = 18,5981 m

l = 18,5981 m

t = 6,1994 m

Spesifikasi :

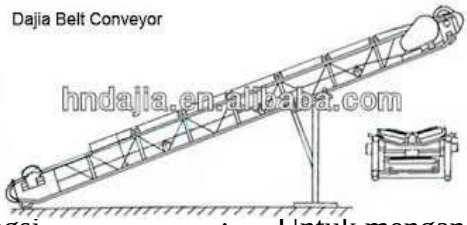
Fungsi : Untuk menyimpan aluminium sulfat sementara waktu sebelum diprose

Bentuk : Bangun segiempat

Kapasitas = 2144,292573 kg

Waktu penyimpanan = 30 hari
Dasar pemilihan = Sesuai dengan bahan solid
Ukuran bangunan = p = 18,5981 m
l = 18,5981 m
t = 6,1994 m
Bahan kontruksi = Beton
Jumlah = 1

2. BELT CONVEYOR (J-111)



Fungsi : Untuk mengangkut Aluminium sulfat dari gudang
Type : Troughed belt on 45^o idlers with rolls of equal length
Dasar pemilihan : Dipilih conveyor jenis belt sesuai dengan bahan

Perhitungan :
Rate massa = 6908,6301 kg/jam
= 6,9086 ton/jam
Kapasitas = 6,9086 ton/jam
dipilih belt conveyor dengan spesifikasi sebagai b Perry ed 7 Tabel 21-7
Kapasitas maksimum : 32 ton/jam
Belt width : 14 in
Belt speed : 100 ft/min
hp/10 ft, lift : 0,34 hp/ft
Through width : 9 in
Skirt seal : 2 in

Asumsi : jarak belt conveyor ke cutter = 50 ft
tinggi belt ke cutter = 10 ft
slope = α
$tg\ \alpha = \frac{10}{50} = 0,2$
α = 11,31 ^{o}
Panjang belt = $\sqrt{(10^2 + 50^2)}$ = 50,9902 ft

Perhitungan power :
hp/10 ft, lift = 0,34 hp/ft

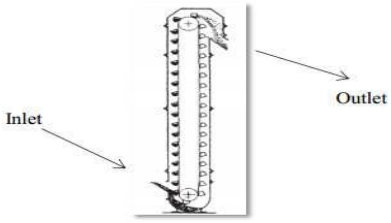
hp = $\frac{50,9902}{10}$ x 0,34 = 1,7337

Penambahan power untuk tripper = 2 hp
Power total = 3,7337 hp

Spesifikasi :

Fungsi	:	Untuk mengangkut aluminium sulfat dari gudang l bucket elevator
Type	:	Troughed belt on 45^o idlers with rolls of equal length
Kapasitas maksimum	:	32 ton/jam
Dasar pemilihan	:	Sesuai untuk bahan solid
Belt width	:	14 in
Belt speed	:	100 ft/min
Trough width	:	9 in
Skirt seal	:	2 in
Panjang	:	50,9902 ft
Sudut elevansi	:	11,31 ^{o}
Power	:	3,73367 hp
Jumlah	:	1 buah

3. BUCKET ELEVATOR (J-112)



Fungsi : Untuk mengangkut aluminium sulfat dari belt conveyor ke hoppe
Type : Centrifugal discharge elevator
Bahan : Carbon Steel
Perhitungan :
Rate massa = 6908,6301 kg/jam
= 15230,9042 lb/jam
ρ bahan = 180,9445225 lb/cuft
Data dari Perry ed 7 Tabel 21-8
Tinggi bucket = 50 ft
Putaran poros = 43 rpm

Untuk kapasitas maksimum = 14 $\frac{ton}{jam}$ Kecepatan buket elevator sebesar 225 ft/menit

Sehingga untuk kapasitas = 6,9086 ton/jam

maka,

Kecepatan bucket elevator = $\frac{6,9086}{14}$ x 225

= 111,0316 ft/menit

Power pada head shaft = 1,6 hp

Power tambahan = 2% hp tiap ft

= 0,02 hp/ft x 50 ft

= 1 hp

P total = 1,6 + 1

= 2,6

Ukuran Bucket = 6" x 4" x 4,25"

Bucket spacing = 12 in

Efisiensi motor = 80%

Maka motor penggerak yang digunakan = $\frac{2,6}{0,8}$

= 3,25 hp

Spesifikasi :

Fungsi : Untuk mengangkut $Al_2(SO_4)_3$ dari belt conveyor ke hopper

Type : Continous discharge bucket elevator

Dasar pemilihan Dapat memindahkan bahan dengan ketinggian tertentu

Kapasitas : 14 ton/jam

Tinggi Bucket : 50 ft

Kecepatan Bucket : 111,0316 ft/menit

Bucket Spasing : 12 in

Ukuran Bucket : 6" x 4" x 4,25"

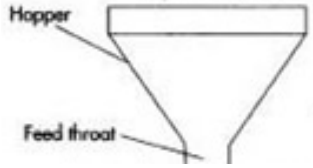
Putaran head shaft : 43 rpm

Lebar belt : 7 in

Power : 3,25 hp

Jumlah : 1 buah

4. HOPPER ALUMINIUM SULFAT (F-113)



Fungsi : Menampung sementara aluminium sulfat sebelum masuk tangki pelarut

Type : Silinder dengan tutup bawah berbentuk konical dengan posisi vertikal

Komposisi bahan :

Bahan Masuk

Komponen	Berat	Fraksi berat	ρ (gr/cm)
Al2(SO4)3	5285,792926	0,7651	2,67
AL2O3	1576,480313	0,2282	3,99
Fe2O3	46,35690829	0,0067	5,25
Total	6908,630147	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}7651}{2{,}67} + \frac{0{,}2282}{3{,}99} + \frac{0{,}0067}{5{,}25}} \times 62{,}43$$

$$= 180{,}9445 \text{ lb/cuft}$$

Rate Massa = 6908,630147 kg/jam
= 15233,52947 lb/jam

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

$$= \frac{15233{,}52947 \text{ lb/jam}}{180{,}9445 \text{ lb/cuft}}$$

$$= 84{,}1890 \text{ cuft/jam}$$

Perancanaan Dimensi Hopper

Asumsi waktu tinggal hopper = 2 jam
Bahan masuk = 15233,52947 lb/jam
Volume bahan = 84,1890 cuft/jam x 2
= 168,3779013 cuft
ρ campuran = 180,9445 lb/cuft

Asumsi volume bahan mengisi 80% volume tangki sehingga volume ruang kosong sebesar 20% dan digunakan 1 buah tangki

$$\text{Volume tangki} = \frac{168{,}3779013}{0{,}8}$$

$$= 210{,}4723767 \text{ cuft}$$

Safety factor = 10%
Volume tangki = 210,4723767 x 1,1
= 231,5196

Menentukan ukuran Hopper dan ketebalannya

Tinggi conical :

$$H = \frac{tg\ \alpha \times (D - m)}{2}$$ (Hesse: 92 pers 4-17)

Keterangan :

α = sudut conis : 30^o

D = diameter tangki : ft

m = flat spot center : 12 in → 1 ft 0

Ditentukan :

Diameter atas = 3,5 ft

maka,

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

$$= \frac{0,577 \times (3,5 - 1)}{2}$$ (Hesse: 92 pers 4-17)

= 0,7213 ft

Volume conical = 0,262 h (D^2 + D . m + m^2)

= 0,262 x 0,7213 x 16,75

= 3,1652 cuft

Volume shell = 231,5196 - 3,1652

= 228,3544 cuft

Volume shell = 3,14 . D^2 . H/4

228,3544 = 3,14 . D^2 . H/4

H = 23,7467 ft

Jadi tinggi total = 0,7213 + 23,7467

= 24,4680 ft

Tekanan bahan $= \frac{Density\ .\ H}{144}$

$= \frac{180,9445 \times 24,4680}{144}$

= 30,74545405

P oprasi = 14,7 psi

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

P design = 1,1 x P perencanaan

= 1,1 x (14,7 + 30,745454)

= 49,98999945 psig

Menentukan tebal minimum shell :

$$t_{min} = \frac{P \times ri}{fe - 0{,}6P} + C \qquad \text{(Brownell : Pers 13-1)}$$

dengan :

t_{min} = tebal shell minimum ; in
P = tekanan tangki ; psi
ri = jari0jari tangki ; in (1/2 D)
C = faktor korosi ; in (1/8 in)
E = faktor pengelasan, digunakan dobel welded
e = 0,8 (Brownell : 13-2)
f = stress allowable, bahan konstruksi carbon steel SA-283 grade C, maka : f = 12650 (Brownell : 13-1)

r = 1/2 x 3,5
= 1,75 ft
= 21 in

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

$$= \frac{49{,}98999945 \times 21}{10120 - 29{,}99399967} + 0{,}125$$

= 0,2290 + 0,125
= 0,3540 in → digunakan t = 3/8 in

Penentuan tebal tutup bawah
Jenis : Conical
Type las : Double welded butt joint effisiensi 80%
(Brownell : 13-2)
Tebal tutup :

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

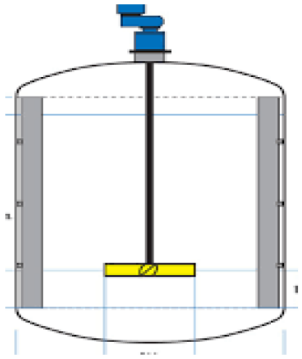
$$= \frac{49{,}98999945 \times 21}{2\cos 24\,(12650\ 0{,}8 - 1 \times 49{,}99)} + 0{,}125$$

= 0,247639913 in → $\frac{1}{4}$ in

Spesifikasi hopper :
Fungsi : Menampung sementara Al2(SO4)3 sebelum masuk tangki pelarut
Type : Silinder dengan tutup bawah berbentuk konical dengan posisi vertikal
Kapasitas : 168,3779013 cuft

Diameter dalam silinder	:	3,5	ft
Tinggi silinder	:	23,7467213	ft
Tebal shell	:	0,375	in
Diameter atas conical	:	3,5	ft
Diameter bawah conical	:	1	ft
Tinggi conical	:	0,7213	ft
Cone angle	:	30	^{o}
Tebal angle	:	0,25	in
Jumlah	:	1 buah	

5. TANGKI PELARUT ALUMINIUM SULFAT (M-120)



Fungsi : Melarutkan aluminium sulfat dengan air proses
Type : Silinder tegak, tutup atas dished, tutup bawah conis dilengkapi pengaduk

Kondisi oprasi :

Tekanan oprasi	=	1	atm	(tekanan atmosfer)
Suhu oprasi	=	30	^{o}C	(suhu kamar)
Waktu tinggal	=	60	menit	

Dimensi ratio, H/D
ditetapkan → H = 2 D

Perhitungan :

Komposisi bahan masuk

Komponen	Berat	Fraksi berat	ρ (gr/cm^3)
$Al_2(SO_4)_3$	5285,7929	0,2644	2,67
Al_2O_3	1576,4803	0,0789	3,99
Fe_2O_3	46,3569	0,0023	5,25
H_2O	13083,6459	0,6544	1
Total	19992,276	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}2644}{2{,}67} + \frac{0{,}0789}{3{,}99} + \frac{0{,}002}{5{,}25} + \frac{0{,}65}{1}} \times 62{,}43$$

$$= 80{,}6941 \text{ lb/cuft}$$

a. Penentuan Volume Tangki

Densitas campuran = 80,6941 lb/cuft
Rate Produk = 19992,276 kg/jam
= 44075,372 lb/jam

ρ campuran = ρ bahan

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

$$= \frac{44075{,}372 \text{ lb/jam}}{80{,}6941 \text{ lb/cuft}}$$

$$= 546{,}2033915 \text{ cuft/jam}$$

Direncanakan waktu oprasi sebesar 1 jam dengan 1 buah tangki, sehingga :
Volume Bahan = 546,2033915 x 1
= 546,2033915 cuft
Volume bahan mengisi 80% volume tangki, sehingga volume tangki :

$$\text{Volume Tangki} = \frac{546{,}2033915}{0{,}8}$$

$$= 682{,}7542 \text{ cuft}$$

$V_s = (\pi/4) \times Ds^2 \times Hs$
$= (\pi/4) \times Ds^3 \times 2$
$= 1{,}5714\ Ds^3$

$V_{\text{tutup atas}} = 0{,}000049\ Ds^3$ (Brownell : 88)

$V_{\text{tutup bawah}} = (\pi\ Ds^3) / 24$ (Hesse, 1962)

$$= \frac{3{,}14 \times Ds^3}{24}$$

$= 0{,}1308\ Ds3$

$V_t = V_s + V_{\text{tutup atas}} + V_{\text{tutup bawah}}$

$682{,}7542 = 1{,}5714\ Ds^3 + 0{,}000049\ Ds^3 + 0{,}1308\ Ds^3$

682,7542 = 1,7023 Ds^3

D = 7,3747 ft

≈ 7,0 ft = 84 in

H = 14,7493 ft

≈ 15 ft = 174 in

b. Tebal Shell

Tinggi liquid dalam shell :

Volume liquid = V_s + V_{alas}

546,2034 = (π/4) x h x Ds^2 + 0,1308 Ds^3

546,2034 = 0,785 x h x 49,000 + 0,1308 x 343

h = 13,0333 ft

= 3,9726 m

c. Menentukan Tekanan Design

P_{oprasi} = 1 atm ⟶ 14,7 psi

$P_{hidrostatis}$ = ρ x (g / gc) x h

$$= \frac{80,6941 \times 1 \times 13,0333}{144}$$

= 7,3036 psi

P_{design} = (P_{oprasi} + $P_{hidrostatis}$) x 1,1

= (14,7 + 7,3036) x 1,1

= 24,2039 psi

Dipergunakan bahan konstruksi yang terbuat dari Carbon Steel dengan spesifikasi SA 283 grade C

$f_{allowable}$ = 12650 (Brownell : T13.1)

C = 0,125 in

Sambungan las dengan type double welded butt joint

Efisiensi las, E = 0,8

r = 1/2 x 84

= 42 in

Rumus tebal shell yang digunakan adalah :

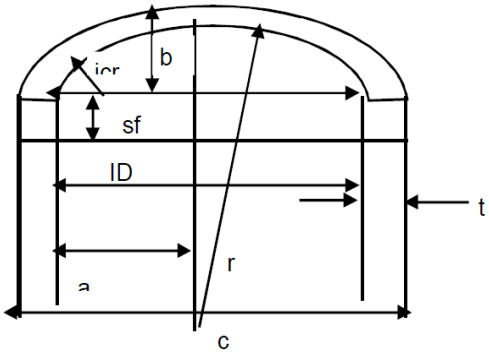
$$t_{min} = \frac{P \times ri}{fe - 0,6P} + C$$ (Brownell : Pers 13-1)

$$= \frac{24,2039 \times 42}{((12650 \times 0,8) - (0,6 \times 24,204))} + 1/8$$

= 0,2256 in

Diambil tebal shell = 1/4 in

Penentuan dimensi tutup atas, dished



Tutup atas berbentuk standart dished

OD = ID + 2ts
= 7,0 + 2 x 1/4
= 7 1/2 ft
= 90 in
rc = 7 1/2 ft
rc = L

Tinggi tutup (h) = $L - (L^2 - (D^2/4))^{0,5}$ (Hesse, 1962)
= $7\ 1/2 - (56\ 1/4 - 12,25)^{0,5}$
= 0,8668 ft

Volume dishead = $1,1 \times h^2 (3rc - h)$
= 1,1 x 0,7513 x (3 x 7 1/2 - 0,8668)
= 17,8773 cuft

Bentuk : Flanged and standart dishead head

Tebal standart toripherical dished (atas)

$$t = \frac{0,885 \times P_d \times r_c}{(f \times E - 0,1P_d)}$$ (Brownell & Young, 1959)

Dimana :

P_d = Tekanan desain (psi)
r_c = Diameter luar (m)
E = Faktor Pengelasan 80%
t = Tebal dinding minimal (in)

$$t = \frac{0,885 \times 24,2039 \times 90}{(12650 \times 0,8) - (0,1 \times 24,2039)}$$

t = 0,1905 in

Diambil tebal head sebesar 1/4 in

Tutup bawah berbentuk conical

$$h = \frac{tg\alpha \times (D - m)}{2}$$ (Hesse, 1962)

Dimana :

D : Diameter bejana (ft)

tgα : Sudut Conis 30^o

m : 12" = 1 ft

$$h = \frac{tg\ 30^o \times (7 - 1)}{2}$$

h = 1,7321 ft

Volume conical = 0,262 h (D^2 + D m + m^2)

= 0,262 x 1,7321 x 57

= 25,8664 cuft

Bentuk : Standart conical dished

$$t = \frac{P_d \times r_c}{2 \cos Alfa\ (f E - 0{,}6P_d)} + C$$ (Brownell; 259)

Dimana :

P_d = Tekanan desain (psi)

E = Faktor pengelasan 80%

t = Tebal dinding minimal (in)

$$t = \frac{(25{,}8664 \times 90)}{2 \cos 30\ ((12650\ 0{,}8) - (1 \times 25{,}866))} + 1/8$$

t = 0,8718 in

Diambil tebal head 7/8 in

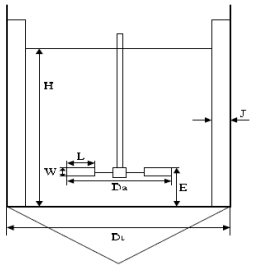
Sistem Pengaduk

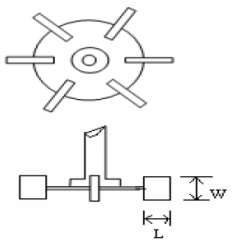
Dipilih pengaduk type flat blade turbine dengan jumlah blade 6

1. Penentuan Dimensi Pengaduk

Tinggi bahan total H_L = 13,0333 = 156,4001 in

Diameter dalam tangki D_t = 7 = 84 in





Ukuran pengaduk diambil dari (Mc. Cabe: 247) :

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

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

$\frac{W}{Da} = \frac{1}{5}$

Diameter impeler (Da) = 1/3 diameter sl $= \frac{1}{3} \times 7 = 2{,}3333$ ft

Lebar blade (w) = 1/5 diameter impeller $= \frac{1}{5} \times 2{,}3 = 0{,}4667$ ft

Panjang blade (L) = 1/4 diameter impell $= \frac{1}{4} \times 2{,}3 = 0{,}5833$ ft

Jarak impeler dari dasar (E) = 1/3 diame $= \frac{1}{3} \times 7 = 2{,}3333$ ft

Lebar baffle (J) = 1/12 diameter shell $= \frac{1}{12} \times 7 = 0{,}5833$ ft

Tebal pengaduk $= \frac{1}{10} \times 0{,}5833 = 0$ ft $= 0{,}7$ in

Keterangan :

Da	=	Diameter pengaduk
Dt	=	Dimeter tangki
L	=	Panjang blade
W	=	Lebar blade
E	=	Jarak pengaduk dari dasar tangki
J	=	Lebar baffle

2. Penentuan Jumlah Pengaduk

Tinggi bahan total H_L = 13,0333 ft

Diameter dalam tangki D_t = 7 ft

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

$$= \frac{80{,}6941 \text{ lb/cuft}}{62{,}303 \text{ lb/cuft}}$$

$$= 1{,}2952$$

$$\text{Jumlah impeler} = \frac{\text{tinggi larutan}}{\text{diameter bejana}} \times sg$$

$$= \frac{13{,}0333}{7} \times 1{,}2952$$

$$= 2{,}4115$$

Jadi jumlah impeler sebanyak = 2 buah

3. Penentuan Power Motor

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

$$= \frac{1{,}2952 \times 0{,}001}{0{,}996}$$

= 0,0013 lb/ft dt (berdasarkan sg bahan)

ρ campuran = 80,6941 lb/cuft

Kecepatan putaran pengadukan jenis turbin antara 200-250 m.min

Ditetapkan kecepatan pengaduk, (N) = 110 rpm = 2 rps

Putaran pengaduk, V = π x N x Da (Joshi: 389)

= π x 110 x (2,3333 x 1/3)

= 268,8889 m/min (memenuhi)

Bilangan Reynolds (Nre)

$$\text{Nre} = \frac{\rho \times D^2 \times N}{\mu} = \frac{80{,}6941 \times 5{,}4444 \times 2}{0{,}001}$$

= 878668,6986 (aliran trubulen)

Perhitungan power pengaduk yang dibutuhkan :

Diperoleh nilai Nre > 10000, sehingga Np = K_T

K_T = Np = 1,2 (Ludwig, Fig 5-13)

$$P = \frac{K_T N^3 Da^5 \rho}{gc}$$ (Mc Cabe : 257 Pers 9.12b)

$$P = \frac{1{,}2 \times 8 \times 69{,}1646 \times 80{,}6941}{32{,}17}$$

= 1665,50403 ft.lbf/s

= 1665,50403 / 550

= 3,0282 hp

(Joshi, 1981)

Power Losses pada Gland 10% hp = 0,1 x 3,0282

= 0,3028 hp

Diambil power = 0,5 hp

Power input dengan gland losses = 3,0282 + 0,3028

= 3,3310 hp

Transmission sistem losses 20% = 0,2 x 3,3310

= 0,6662 hp

Power total = 3,3310 + 0,6662

= 3,9972 hp

Karena jumlah pengaduk 2 buah, maka powe = 2 x 3,9972

= 7,9944 hp

Efesiensi motor = 85%

Sehingga power motor = $\frac{7,9944}{0,85}$

= 9,405199228 hp ≈ 9,4 hp

Spesifikasi :

Dimensi Shell :

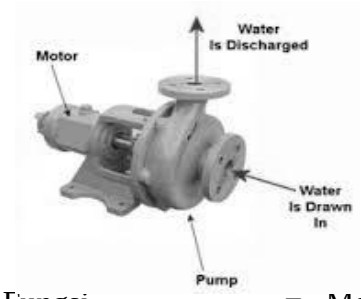
Diameter shell, inside	:	7	ft
Tinggi Shell	:	14,5	ft
Tebal Shell	:	1/4	in
Tebal tutup (dished)	:	1/4	in
Tebal tutup (conical)	:	7/8	in

Sistem pengaduk

Dipakai impeler jenis turbin dengan 6 buah flat blade dengan 2 impeller

Diameter impeller	:	2,3333	ft
Panjang blade	:	0,5833	ft
Lebar Blade	:	0,4667	ft
Power motor	:	9	hp
Bahan konstruksi	:	Carbon steel SA-283 grade C	
Jumlah tangki	:	1 buah	

6. POMPA -1 (L-121)



Fungsi = Memindahkan bahan dari tangki pelarut 1 ke clarifier

Type = Centrifugal Pump

Dasar pemilihan = Sesuai untuk viskositas <10 cP dan bahan liquid

Bahan Masuk

Komponen	Berat	Fraksi berat	ρ (gr/cm^3)
$Al_2(SO_4)_3$	5285,7929	0,2644	2,67
Al2O3	1576,4803	0,0789	3,99
Fe2O3	46,3569	0,0023	5,25
H_2O	13083,6459	0,6544	1
Total	19992,276	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}2644}{2{,}67} + \frac{0{,}0789}{3{,}99} + \frac{0{,}0023}{5{,}2500} + \frac{0{,}6544}{1}} \times 62{,}43$$

$$= 80{,}6941 \text{ lb/cuft}$$

ρ campuran = ρ bahan

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

$$= \frac{80{,}6941 \text{ lb/cuft}}{62{,}303 \text{ lb/cuft}} \times 0{,}996$$

$$= 1{,}2900$$

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

$$= \frac{1{,}2900 \times 0{,}001}{0{,}996}$$

$$= 0{,}0013 \text{ lb/ft dt} \quad \text{(berdasarkan sg bahan)}$$

Data perhitungan :

Rate bahan = 19992,276 kg/jam
= 44075,372 lb/jam

ρ bahan = 80,6941 lb/cuft
= 1,2927 gr/ml

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

$$= \frac{44075{,}372 \text{ lb/jam}}{80{,}6941 \text{ lb/cuft}}$$

= 546,2033915 cuft/jam
= 9,1034 cuft/menit
= 68,0981 gpm

Viskositas (μ) = 0,0013 lb/ft s
= 1,9275 cp

Perhitungan diameter pipa

Asumsi aliran Turbulen :

Diameter optimum untuk turbulen, Nre >4000 digunakan persamaan :

Di optimum = $3.9 \times qr^{0,45} \times \rho^{0,13}$ (Peters, ed.4 pers.15 hal 496)

Dengan : qr = Fluid flow rate , ρ = fluid density ; lb cuft

qr = 9,1034 cuft/menit
= 0,15172 cuft/s

Diameter pipa optimum = $3.9 \times qr^{0,45} \times \rho^{0,13}$ (Peters, ed.4 pers.15 hal 496)
= 2,9541 in

Dipilih pipa 3 in, sch 80 ;

OD = 3,5 in 0,29167 ft
ID = 2,9 in 0,24167 ft

Luas , A = $(1/4.\ \pi.\ ID^2)$
= 0,0458 ft^2

Kecepatan aliran (V) = $\frac{\text{Rate volumetrik cuft/dt}}{\text{Luas, A } ft^2}$ g = 416061544,8
= 3,3094 ft/dt

$$Nre = \frac{D\ V\ \rho}{\mu} = \frac{0,24167 \times 3,3094 \times 80,6941}{0,001295187}$$
= 49828,1132 > 4000 (asumsi turbulen benar)

Menentukan jumlah energi yang hilang

1. Karena pipa lurus

Ditetapkan :

Panjang pipa lurus = 10 ft
Dipilih pipa Galvanized iron = 0,00015 (Geankoplis: 88)
maka harga e/D = 0,003
f = 0,006 (Geankoplis: 88)
gc = 32,174 ft.lbm/dt².lbf

2. Karena friksi (Geankoplis: 88)

Taksiran panjang pipa lurus						=	10	ft
2 elbow 90°	=	2	x	32	x ID pipa	=	15,4667	ft
1 gate valve	=	1	x	9	x ID pipa	=	2,175	ft
Panjang total pipa						=	27,6417	ft

Friksi yang terjadi :

1. Friksi karena gesekan bahan dalam pipa :

$$F1 = (2f \times V^2 \times Le)/(gc \times D)$$ = 0,46722 ft. lbf / lbm

2. Friksi karena kontraksi dari tangki ke pipa:

$$F2 = (K \times V2^2)/(2 \times \alpha \times gc)$$ = 0,00851 ft. lbf / lbm

(α= 1 untuk aliran turbulen)
(K= 0,1 A tangki >>>Apipa)
(Peters ed.4 hal 484)

3. Friksi karena ekspansi dari pipa ke tangki:

$$F_3 = \frac{V^2}{2 \times \alpha \times gc} = \frac{\Delta V_2^{\,2} - \Delta V_1^{\,2}}{2 \times \alpha \times gc} = 0{,}1702 \ \frac{\text{ft. lbf}}{\text{lbm}}$$

(V_1 <<<< V_2, maka V_1 dianggap = 0)

4. Friksi karena Elbow 90^o

$$F_4 = \frac{K_f \times V_1^{\,2}}{2} = \frac{0{,}75 \times 10{,}952}{2} = 4{,}1070$$

5. Friksi karena Gate Valve

$$F_5 = \frac{K_f \times V_1^{\,2}}{2} = \frac{0{,}17 \times 10{,}952}{2} = 0{,}9309$$

ΣF(Total Friksi)

$$= F_1 + F_2 + F_3 + F_4 + F_5$$
$$= 0{,}4672 + 0{,}0085 + 0{,}1702 + 4{,}107 + 0{,}9309$$
$$= 5{,}6839 \ \frac{\text{ft.lb}_f}{\text{lb}_m}$$

Persamaan Bernoulli :

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

$P_1 = P_{hidrostatis}$

Diketahui data dari bak pengendapan

Tinggi bahan = 13,0333 ft

ρ bahan = 80,6941 lb/cuft

$P_{hidrostatis} = \rho \cdot g/gc \cdot H$

= 80,6941 x 13,0333

= 1051,713458 lb/ft^2

P_2 = 1 atm = 14,7 psi

= 14,7 x 144

= 2116,8000 lbf/ft^2

$$\Delta P = P_2 - P_1$$
$$= 2116{,}80 - 1051{,}7$$
$$= 1065{,}0865 \ lb_f/ft^2$$

$$\frac{\Delta P}{\rho} = \frac{1065{,}0865 \ lb_f/ft^2}{80{,}6941 \ lb_m/ft^3}$$
$$= 13{,}1991 \ \frac{ft.lb_f}{lb_m}$$

Energi Potensial

$Z_2 = 3$ ft clarifier

$Z_1 = 13{,}033$ ft

Asumsi : $g/gc = 1$

g percepatan gravitasi $= 32$ ft/dt^2

gc konstanta gravitasi $= 32$ $ft/dt^2 \times lb_m/lb_f$

$$\Delta Z \frac{g}{gc} = 10{,}0333 \ ft \times \frac{32 \ ft/dt^2}{32 \ ft.lb_m/dt^2.lb_f}$$
$$= 10{,}0333 \ \frac{ft \ . \ Lbf}{lbm}$$

Energi Kinetik

$$\frac{\Delta V^2}{2 \times gc \times \alpha} = \frac{10{,}9521}{2 \times 32{,}2 \times 1}$$
$$= 0{,}1701 \ \frac{ft.lb_f}{lb_m}$$

$$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \times gc \times \alpha} + \Sigma F$$
$$= 13{,}20 + 10{,}0333 + 0{,}1701 + 5{,}684$$
$$= 29{,}0864 \ \frac{ft.lb_f}{lb_m}$$

$$hp = \frac{Wf \times qr \times \rho}{550}$$
$$= \frac{29{,}09 \times 0{,}1517 \times 80{,}6941}{550}$$
$$= 0{,}6475 \ hp$$

Effisiensi pompa = 22% (Peters & Timmerhaus : fig 14-36)

$$\text{Bhp} = \frac{\text{hp}}{\eta \text{ motor}} = \frac{0{,}6475}{0{,}22} = 2{,}94305037 \text{ hp}$$

Effisiensi motor = 81% (Peters&Timmerhaus : fig 14-38)

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

$= \frac{2{,}94}{81\%}$

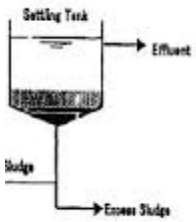
= 3,6 hp

digunakan power = 3,6 hp

Spesifikasi :

Fungsi = Mengalirkan produk bak penampung ke heater
Jenis = Pompa centrifugal
Kapasitas = 19992,276 kg/j
Power = 3,6 hp
eff. Pompa = 22%
eff. Motor = 81%
Jumlah = 1 pompa
Bahan kontruksi = Carbon Stell

7. BAK PENGENDAPAN (H-122)



Fungsi : Tempat pemisahan antara impiuritis tak larut dari tangki pelarut
Type : Circular, radial flow tank
Bentuk : Berbentuk silinder tegak dan bagian bawah conis

Perhitungan :

Komposisi bahan masuk

Komponen	Berat	Fraksi berat	ρ (gr/cm^3)
$Al_2(SO_4)_3$	5285,7929	0,2644	2,67
Al_2O_3	1576,4803	0,0789	3,99
Fe_2O_3	46,3569	0,0023	5,25
H_2O	13083,6459	0,6544	1
Total	19992,276	1	

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ komponen}} \text{ x}} \text{ x } 62{,}43$$

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}2644}{2{,}67} + \frac{0{,}0789}{3{,}99} + \frac{0{,}0023}{5{,}25} + \frac{0{,}6544}{1}} \text{ x } 62{,}43$$

= 80,6941 lb/cuft

Densitas campuran = 80,6941 lb/cuft
Rate Produk = 17450,96684 kg/jam
= 38472,751 lb/jam

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

$$= \frac{38472{,}751 \text{ lb/jam}}{80{,}6941 \text{ lb/cuft}}$$

= 476,7729934 cuft
= 13,50070934 m3

Direncanakan menggunakan 1 clarifier, sehingga

$$\text{Debit air} = \frac{13{,}501}{1}$$

= 13,5007 m^3/jam

Laju alir limpahan (Overflow rate) = 13 m^3/m^2.hari
= 0,5417 m^3/m^2.jam

$$A = \frac{Q}{v}$$

$$= \frac{13{,}5007}{0{,}5417}$$

= 24,9244 m^2

$$D = \left(4 \text{ x } \frac{A}{\pi} \right)^{(1/2)}$$

= 5,6348 m
r = 2,8174 m

Diameter pipa umpan masuk d' = 0,15 D
= 0,84522 m

Kedalaman Clarifier (H) = D/H = 6

$$H = \frac{D}{6}$$

$$= \frac{5{,}635}{6}$$

$$= 0{,}9391 \text{ m}$$

Asumsi, s = 2 m → s/s' = 4

$$s' = \frac{2}{4} = 0{,}5 \text{ m}$$

Asumsi :

Tinggi Cone (Hc) $= \frac{1}{2}$ Hs

$= \frac{1}{2}$ 0,9391

= 0,46957 m

Volume = A * Hs

= 24,9244 * 1,4087

= 35,11 m^3

Waktu Tinggal = V / Q

$$= \frac{35{,}11}{13{,}5007}$$

= 2,6 jam , memenuhi standart yaitu 1,5 - 2,5 jam

Spesifikasi Clarifier

Fungsi : Tempat pemisahan antara flok atau padatan dengan air bersil dengan cara sedimentasi atau pengendapan

Tipe : Circular, radial flow tank

Bentuk : Berbentuk silinder tegak dan bagian bawah conis

Kapasitas : 35,1109 m^3

Waktu Tinggal : 2,6 jam

Dimensi

Diameter Silinder : 5,6348 m

Tinggi Silinder : 0,9391 m 4,6217

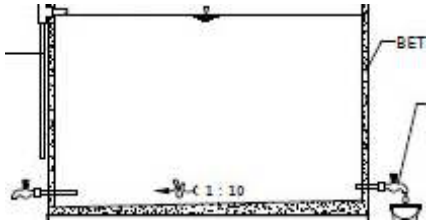
Tinggi Conis : 0,4696 m

Diameter pipa umpan : 0,8452 m

Bahan Konstruksi : Beton

Jumlah : 1 buah

8. BAK PENAMPUNG IMPURITIS (F-123)



Fungsi : Menampung impuritis dari clarifier
Type : Bak berbentuk persegi panjang, terbuat dari beton
Bahan masuk :

Komponen	Berat	Fraksi berat	ρ (gr/cm^3)
$Al_2(SO_4)_3$	264,2896	0,1040	2,67
Al_2O_3	1576,4803	0,6203	3,99
Fe_2O_3	46,3569	0,0182	5,25
H_2O	654,1823	0,2574	1
Total	2541,3092	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}1040}{2{,}67} + \frac{0{,}6203}{3{,}99} + \frac{0{,}0182}{5{,}25} + \frac{0{,}2574}{1}} \times 62{,}43$$

$$= 137{,}1128 \text{ lb/cuft}$$

Densitas campuran = 137,1128 lb/cuft
Rate Produk = 2541,3092 kg/jam
= 5602,621 lb/jam
Waktu tinggal = 24 jam
ρ campuran = ρ bahan

$$\text{Rate volumetrik} = \frac{\text{rate massa}}{\rho \text{ campuran}} \times \text{waktu tinggal}$$

$$= \frac{5602{,}621 \text{ lb/jam}}{137{,}1128 \text{ lb/cuft}} \times 24 \text{ jam}$$

$$= 980{,}6733824 \text{ cuft}$$

Dimisalkan :
Panjang = 4 X m
Lebar = 3 X m
Tinggi = 2 X m

Volume bak penampung (direncanakan 80% terisi impuritis) :

$$= \frac{980,6733824}{0,8}$$

= 1225,841728 cuft

Volume bak penampung	=	p	x	l	x	t		
1225,841728	=	4 X	x	3 X	x	2 X		
1225,841728	=	24	X^3					
X	=	3,7103						

Maka,

Panjang	=	4 X	m	=	4	x	3,7103	=	14,8412	ft
Lebar	=	3 X	m	=	3	x	3,7103	=	11,1309	ft
Tinggi	=	2 X	m	=	2	x	3,7103	=	7,4206	ft

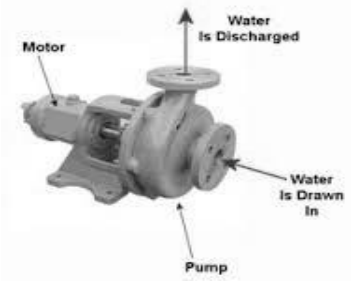
Check volume :

Volume bak	=	p	x	l	x	t	
	=	14,8412	x	11,1309	x	7,4206	
	=	1225,8417	cuft	≈	1225,8417	cuft	(memenuhi)

Spesifikasi :

Fungsi	=	Menampung impuritis dari bahan Al_2SO_4			
Kapasitas	=	1225,8417	cuft		
Bentuk	=	Empat persegi panjang terbuka			
Ukuran	=	Panjang	=	14,8412 ft	4,52358 m
		Lebar	=	11,1309 ft	3,39269 m
		Tinggi	=	7,4206 ft	2,26179 m
Bahan kontruksi	=	Beton			
Jumlah	=	1 buah			

9. POMPA -2 (L-124)



Fungsi	=	Memindahkan bahan dari bak pengendapan ke heater
Type	=	Centrifugal Pump

Dasar pemilihan = Sesuai untuk viskositas <10 cP dan bahan liquid

Bahan Masuk

Komponen	Berat	Fraksi berat	ρ (gr/cm^3)
$Al_2(SO_4)_3$	5021,5033	0,2877	2,67
H_2O	12429,4636	0,7123	1
Total	17450,967	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}2877}{2{,}67} + \frac{0{,}7123}{1}} \times 62{,}43$$

$$= 76{,}1321 \text{ lb/cuft}$$

ρ campuran = ρ bahan

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

$$= \frac{76{,}1321 \text{ lb/cuft}}{62{,}303 \text{ lb/cuft}} \times 0{,}996$$

$$= 1{,}2171$$

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

$$= \frac{1{,}2171 \times 0{,}001}{0{,}996}$$

$$= 0{,}0012 \text{ lb/ft dt} \quad \text{(berdasarkan sg bahan)}$$

Data perhitungan :

Rate bahan = 17450,967 kg/jam
= 38472,751 lb/jam

ρ bahan = 76,1321 lb/cuft
= 1,2196 gr/ml

$$\text{Rate volumetrik} = \frac{\text{rate massa}}{\rho \text{ campuran}} \times \text{waktu tinggal}$$

$$= \frac{38472{,}751 \text{ lb/jam}}{76{,}1321 \text{ lb/cuft}}$$

= 505,3420006 cuft/jam
= 8,4224 cuft/menit
= 63,0037 gpm

Viskositas (μ) = 0,0012 lb/ft s
= 1,8185 cp

Perhitungan diameter pipa

Asumsi aliran Turbulen :

Diameter optimum untuk turbulen, Nre >4000 digunakan persamaan :

Di optimum = 3.9 x $qr^{0,45}$ x $\rho^{0,13}$ (Peters, ed.4 pers.15 hal 496)

Dengan : qr = Fluid flow rate , ρ = fluid density ; lb cuft

qr = 8,4224 cuft/menit

= 0,14037 cuft/s

Diameter pipa optimum = 3.9 x $qr^{\circ,45}$ x $\rho^{\circ 13}$ (Peters, ed.4 pers.15 hal 496)

= 2,8310 in

Dipilih pipa 2 1/2 in, sch 80 (Brownell & Young,1987)

OD = 2,875 in 0,23958 ft

ID = 2,323 in 0,19358 ft

Luas , A = (1/4. π. ID^2)

= 0,0294 ft^2

Kecepatan aliran (V) = $\frac{\text{Rate volumetrik}\quad \text{cuft/dt}}{\text{Luas, A}\quad ft^2}$

= 4,7717 ft/dt

$$\text{Nre} = \frac{D\,V\,\rho}{\mu} = \frac{0,19358 \times 4,7717 \times 76,1321}{0,001221965}$$

= 57551,1801 > 4000 (asumsi turbulen benar)

Menentukan jumlah energi yang hilang

1. Karena pipa lurus

Ditetapkan :

Panjang pipa lurus = 15 ft

Dipilih pipa Galvanized iron = 0,00015 (Geankoplis : 88)

maka harga e/D = 0,003

f = 0,006 (Geankoplis : 88)

gc = 32,174 ft.lbm/dt^2.lbf

2. Karena friksi (Geankoplis : 88)

Taksiran panjang pipa lurus							=	15 ft
3 elbow 90°	=	3	x	32	x	ID pipa	=	18,584 ft
1 gate valve	=	1	x	9	x	ID pipa	=	1,74225 ft
Panjang total pipa							=	35,3263 ft

Friksi yang terjadi :

1. Friksi karena gesekan bahan dalam pipa :

$F1 = (2f \times V^2 \times Le)/(gc \times D)$ = 1,54975 ft. Lbf/lbm

2. Friksi karena kontraksi dari tangki ke pipa:

$F2 = (K \times V2^2)/(2 \times \alpha \times gc)$ = 0,01769 ft. lbf / lbm (α= 1 untuk aliran turbulen) (K= 0,05 A tangki >>>Apipa) (Peters ed.4 hal 484)

3. Friksi karena ekspansi dari pipa ke tangki:

$$F_3 = \frac{V^2}{2 \times \alpha \times gc} = \frac{\Delta V_2^2 - \Delta V_1^2}{2 \times \alpha \times gc} = 0{,}35385 \ \frac{\text{ft. lbf}}{\text{lbm}}$$

(V_1 <<<< V_2, maka V_1 dianggap = 0)

4. Friksi karena Elbow 90°

$$F_4 = \frac{K_f \times V_1^2}{2} = \frac{0{,}75 \times 22{,}770}{2} = 8{,}5386$$

5. Friksi karena Gate Valve

$$F_5 = \frac{K_f \times V_1^2}{2} = \frac{0{,}17 \times 22{,}770}{2} = 1{,}9354$$

ΣF(Total Friksi)

= F_1 + F_2 + F_3 + F_4 + F_5

= 1,5497 + 0,0177 + 0,3539 + 8,539 + 1,9354

= 12,3953 $\frac{\text{ft.lb}_f}{\text{lb}_m}$

Persamaan Bernoulli :

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

$P_1 = P_{hidrostatis}$

Diketahui data dari bak pengendapan

Tinggi bahan = 4,6217 ft

ρ bahan = 76,1321 lb/cuft

$P_{hidrostatis}$ = ρ . g/gc .H

= 76,1321 x 4,6217

= 351,8603342 lb/ft^2

P_2 = 1 atm = 14,7 psi
= 14,7 x 144
= 2116,8000 lbf/ft^2

ΔP = $P_2 - P_1$
= 2116,80 - 351,9
= 1764,9397 lb_f/ft^2

$\frac{\Delta P}{\rho} = \frac{1764,9397 \; lb_f/ft^2}{76,1321 \; lb_m/ft^3}$
= 23,1826 $\frac{ft.lb_f}{lb_m}$

Energi Potensial

Z_2 = 13 ft (Reaktor)
Z_1 = 4,622 ft

Asumsi : g/gc = 1
g percepatan gravitasi = 32 ft/dt^2
gc konstanta gravitasi = 32 ft/dt^2 x lb_m/lb_f

$\Delta Z \frac{g}{gc}$ = 8,378 ft x $\frac{32 \; ft/dt^2}{32 \; ft.lb_m/dt^2.lb_f}$
= 8,378 $\frac{ft \, . \, Lbf}{lbm}$

Energi Kinetik

$\frac{\Delta V^2}{2 \times gc \times \alpha} = \frac{22,7696}{2 \times 32,2 \times 1}$
= 0,3536 $\frac{ft.lb_f}{lb_m}$

$-Wf = \frac{\Delta P}{\rho} + \Delta Z \frac{g}{gc} + \frac{\Delta V^2}{2 \; gc \; \alpha} + \Sigma F$
= 23,18 + 8,378 + 0,3536 + 12,395
= 44,3097 $\frac{ft.lb_f}{lb_m}$

$hp = \frac{Wf \times qr \times \rho}{550}$
$= \frac{44,31 \times 0,1404 \times 76,1321}{550}$
= 0,8610 hp

Effisiensi pompa = 20% (Peters & Timmerhaus, fig 14-37)

$$\text{Bhp} = \frac{\text{hp}}{\eta \text{ motor}} = \frac{0{,}8610}{0{,}2} = 4{,}30484197 \text{ hp}$$

Effisiensi motor = 82% (Peters&Timmerhaus, fig 14-38)

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

$= \frac{4{,}30}{82\%}$

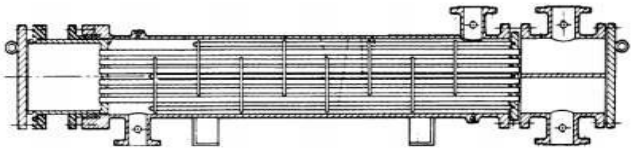
= 5,2 hp

digunakan power = 5,5 hp

Spesifikasi :

Fungsi	=	Mengalirkan produk bak penampung ke heater
Jenis	=	Pompa centrifugal
Kapasitas	=	17450,967 kg/j
Power	=	5,5 hp
eff. Pompa	=	20%
eff. Motor	=	82%
Jumlah	=	1 pompa
Bahan kontruksi	=	Carbon Stell

10. HEATER -1 (E-125)

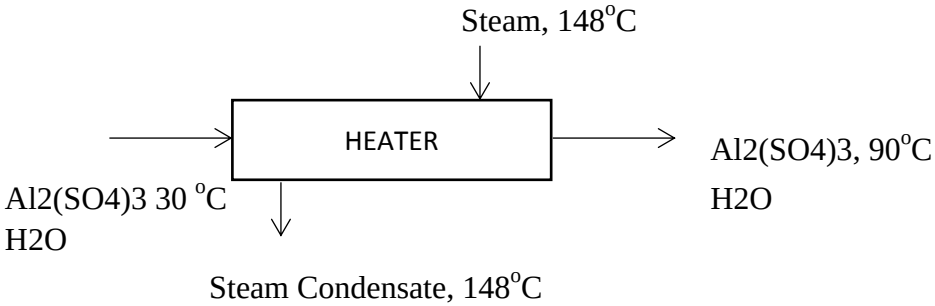


Fungsi : Memanaskan Al2(SO4)3 dari 30 ^{o}C menjadi 90 ^{o}C

Tipe : 1-2 *Shell and tube heat exchanger (Fixed tube)*

Dasar Pemilihan : Umum digunakan pada kapasitas yang besar

Kondisi Operasi :
- Tekanan = 1 atm
- Temperatur = 90 ^{o}C
- Waktu proses : *Continue*



Kondisi Proses :

- **Fluida Dingin**

T masuk (t_1) = 30 ^oC = 86,000 ^oF = 303,15 K

T keluar (t_2) = 90 ^oC = 194 ^oF = 363,15 K

P masuk = 1 atm = 14,700 psia

P keluar = 1 atm = 14,700 psia

- **Fluida Panas**

T masuk (T_1) = 148 ^oC = 298,40 ^oF = 421,15 K

T keluar (T_2) = 148 ^oC = 298,40 ^oF = 421,15 K

P masuk = 4,5 atm = 66,150 psia

P keluar = 4,5 atm = 66,150 psia

Fluida dingin (^oF)		Fluida panas (^oF)	diff
194,00	Higher Temp	298,40	104,40
86,00	Lower Temp	298,40	212,40
108,00	diff	0	108,00

Perhitungan :

1. Data dari neraca Massa dan neraca panas diperoleh :

Panas yang dibutuhkan; Q = 843904,3392 kkal/jam

= 3346924,6092 Btu/jam

Steam yang digunakan : W_{steam} = 1667,0242 kg/jam

= 3675,1549 lb/jam

Wbahan = 17450,9668 kg/jam

= 38479,3819 lb/jam

2. Log Mean Temperature Difference :

Δt_1 = 298,40 - 194,00 = 104,4 ˚F

Δt_2 = 298,40 - 86,000 = 212,4 ˚F

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

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

= 152,1 ˚F

$$R = \frac{T1 - T2}{t2 - t1} = \frac{298,40 - 298,40}{194 - 86}$$

= 0

$$S = \frac{t2 - t1}{T1 - t1} = \frac{194 - 86}{298 - 86} = 0{,}508$$

F_T = 0,75 **(Kern fig 18)** (untuk 1-2 shell and tube)

$\Delta T = F_T \times LMTD$
= 0,75 x 152,0609
= 114,0457 ˚F

3. Tc dan tc
Tc = Tav steam

$$Tc = \frac{T_1 + T_2}{2} = \frac{298{,}40 + 298{,}40}{2}$$

= 298,40 ^oF (μ = 0,015 cp)

tc = tcav bahan

$$tc = \frac{t_1 + t_2}{2} = \frac{86{,}00 + 194{,}00}{2}$$

= 140,00 ^oF (μ = 1,82 cp)

Trial Ud

Hot Fluid = Steam
cold Fluid = water
Ud = 200-700 Btu/ft^{2}j^{o}F **(tabel 8 Kern hal.840)**
Dipilih Ud = 210 Btu/ft^{2}j^{o}F

$$A = \frac{Q}{UD \times \Delta T} = \frac{3346924{,}6092}{210 \times 114{,}05}$$

= 139,7487 ft^2

Direncanakan dengan spesifikasi
Digunakan tube dengan ukuran :
OD, BWG = 3/4 in , 12 BWG
Pitch = 1 in square pitch
Panjang Tube L = 6 ft
Dari kern tabel 10 hal 843 diperoleh :

ID = 0,532 in

a't flow area per tube = 0,223 in^2 = 0,0014 ft^2

a" surface per lin = 0,1963 ft^2

Jumlah Tube Nt $= \frac{A}{a'' \times L}$

$= \frac{139,749}{0,1963 \times 6}$

= 118,65 buah

digunakan Nt = 116 buah

Dari Kern, tabel 9 hal 842, untuk 3/4 in 15 BWG 1 square pitch ;

Tube passes = 4

didapatkan :

ID Shell = 12 in (tabel 9, Kern)

pitch = 1 in square

Fluida Panas (Tube side)	Fluida dingin (Shell side)
4. Flow area (a_b)	**4**. Flow area (a_s)
$a_t = \frac{Nt \times a'_t}{144 \; n}$	$a_s = \frac{ID \,.\, C' \,.\, B}{144 \; P_T}$
	ID = 12 in
Kern, tabel 10	asumsi : B = ID / 5
3/4 OD 12 BWG	= 2 2/5 in
a'_t = 0,223 in^2 (tabel 10)	P_T = 1
$a_t = \frac{116 \times 0,22}{144 \times 4}$	C' = P_T - OD tube
	= 1 - 3/4
= 0,0449 ft^2	= 0,25
	$a_s = \frac{12 \times 0,25 \times 2,4}{144 \times 1}$
	= 0,0500 ft^2
5. Kecepatan massa (G_t)	**5**. Kecepatan massa (G_s)
$G_t = \frac{W}{a_t}$	$G_s = \frac{W}{a_s}$
Wsteam = 3675,15 lb	W fluida = 38479,3819 kg
$G_t = \frac{3675,15}{0,045}$	$G_s = \frac{38479,3819}{0,0500}$

= 81834,283 lb / jam ft^2

6. pada T_c = 298 ^oF

μ = 0,015 cps

= 0,0363 lb / jam.ft

D_i = 0,53 in (Kern,Tabel 10)

= 0,0443 ft

$$Re_t = \frac{D_i \times G_t}{\mu}$$

$$= \frac{0,0443 \times 81834,283}{0,0363}$$

= 99944,5335

= 769587,6377 lb / jam ft^2

tc = 140 ^oF

μ = 1,818 cps

= 4,4007 lb / jam.ft

De' = 0,95 in Kern, fig. 28

= 0,0792 ft

$$Re_s = \frac{D_e \times G_s}{\mu}$$

$$= \frac{0,0792 \times 769587,6377}{4,4007}$$

= 13844,4411

7. j_H = 250 (fig. 24)

8. pada t_c = 140 ^oF

Cp = 0,8600 Btu / lb.^oF (fig 2)

k = 0,15 Btu/jam $ft^2{}^oF$ (tabel 4)

$$\left(\frac{Cp.\mu}{k}\right)^{1/3} = \frac{0,9 \times 4,4007}{0,15}$$

= 2,9330

μw = 1 (standart)

φt = $(\mu/\mu w)^{0,14}$

= 1,231

9. Hio untuk kondensasi steam

hio = 1500 Btu/j ft^2 ^oF (Kern;168)

9'. ho

$$ho = J_H \frac{k}{De}\left(\frac{Cp.\mu}{k}\right)^{1/3} \varphi t$$

$$= 250 \frac{0,15}{0,0792} 2,9330 \; 1,23$$

= 1709,595 Btu/hr.ft^2.^oF

10. U_C = $\frac{hio \times ho}{hio + ho}$

$$= \frac{1500 \times 1709,5946}{1500 + 1709,5946}$$

= 798,9769 BTU/j ft^2 F

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

$$= \frac{3346924,609}{139,749 \times 114,046}$$

= 210,000 BTU/j ft^2 F

Rd hitung = $\frac{U_C - U_D}{U_C \times U_D}$

= $\frac{798,98 - 210,000}{798,98 \times 210,000}$

= 0,0035 J ft^2 F/BTU

Rd perthitungan > Rd data (Kern : T 12)

0,0035 > 0,003 untuk media air

Pressure Drop

Tube Side Bahan	Shell side Steam
1. Re_t = 99944,533 f = 0,00015 ft^2/in^2 *(Kern,Fig 26)* v = 6,2 cuft/lb (Kern, Fig 6) s = $\frac{80,694}{62,5}$ = 1,2911	1'. Re_s = 13844,44 f = 0,00200 ft^2/in^2 s = 1,801 De' = $\frac{4 \times a_s}{(N_t \times \pi \times (0,75/12)) + \pi}$ = $\frac{4 \quad 0,050}{116 \quad 3,1 \quad 0,063 + \quad 3,1}$ = 0,008 ft No. of crosses, (N+1)
2. $\Delta P_t = \frac{f.Gt^2.L.n}{5,22.10^{10}.De.s\,\varphi s}$ $\frac{0,0002 \quad 81834 \quad 6,000 \quad 2,0}{5,22.10^{10} \quad 0,044 \quad 1 \quad 1}$ = 0,0040 psi	2'. N+1 = 12 L / B = 12 6 / 2 = 30 D_s = 12,000 / 12 = 1,000 ft s = 1,0 (Tabel 6)
3. Gt = 81834,3 lb/j ft^2 $\frac{V^2}{2g'}$ = 0,002 (Kern, fig 27)	3'. $\Delta P_s = \frac{f.Gs^2.Ds.(N+1)}{5,22.10^{10}.De.s.\varphi s}$ $= \frac{0,002 \quad 769588 \quad 1,000 \quad 30,0}{5,22.10^{10} \quad 0,079 \quad 1,801 \quad 1}$ = 4,7746 psi ΔP_s < 10 psi
4. $\Delta Pr = \frac{4n}{s} \times \frac{V^2}{2g'}$ = $\frac{4 \quad 2}{1,2911} \times 0,0020$ = 0,012 psi	

$\Delta P_T = \Delta P_t + \Delta Pr$ $= 0,0164$ psi $\Delta P_T < 2$ psi	

Rd perhitungan > Rd data (Kern ; T 12)

0,0035	>	0,0030	untuk media air		memenuhi
$\Delta P_T < 10$ psi	P shell	=	4,774642	psi	memenuhi
$\Delta P_T < 2$ psi	P tube	=	0,0164	psi	memenuhi

Spesifikasi :

Fungsi		Memanaskan $Al_2(SO_4)_3$ sampai suhu 90^oC
Type		Shell and tube, 1-2 exchanger (Fixed tube)
Dasar pemilihan		Umum digunakan dan mempunyai range perpindahan panas yang besar
Shell side	:	
ID	:	12,00 in
B	:	2,40 in
n	:	2 passes
Tube side	:	
Nt	:	116 buah
L	:	6 ft
OD	:	3/4 in
BWG	:	12
n	:	2 passes
Pitch	:	Square pitch 1"
Heat exch, area A	:	139,749 ft2
Jumlah heat exch	:	1
Bahan konstruksi	:	Carbon Steel

11. GUDANG AMONIUM SULFAT (F-130)

Fungsi : Untuk menyimpan $(NH_4)_2SO_4$ untuk sementara waktu sebelum diperoses

Type : Bangunan beratap asbes, berdinding asbes dengan kerangka besi dan lantai semen cor

Bahan masuk :

Komponen	Berat	Fraksi Berat	ρ (gr/cm)
$(NH_4)_2SO_4$	2672,569075	0,9981	1,769
H_2SO_4	0,722938316	0,0003	1,97
H_2O	4,284078907	0,0016	1
Total	2677,576093	1	

Perhitungan :

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{1}{2} + \frac{0{,}00027}{1{,}97} + \frac{0{,}0016}{1}} \times 62{,}43$$

$$= 110{,}3059896 \text{ lb/cuft}$$

Rate Massa = 2677,576093 kg/jam
= 5903,037805 lb/jam

ρ campuran = ρ bahan

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

$$= \frac{5903{,}037805 \text{ lb/jam}}{110{,}3059896 \text{ lb/cuft}}$$

= 53,5151 cuft/jam

Ditentukan :

waktu tinggal = 30 hari (Ulrich, 1984)
Tinggi = x m
Panjang = 3x m
Lebar = 3x m

Volume bahan = 53,5151 cuft/jam
= 53,5151 x 24 x 30
= 38530,88338 cuft

$$\text{Volume gudang (80\% volume bahan)} = \frac{\text{Volume bahan}}{0{,}8}$$

$$= \frac{38530{,}88338}{}$$

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

$$= 48163,6042 \text{ cuft}$$

$$= 1363,03 \text{ m}^3$$

Volume gudang = p x l x t

1363,0300 = 3x x 3x x x

1363,0300 = $9x^3$

$$\frac{1363,0300}{9} = x^3$$

x^3 = 151,4478

x = 5,3303

p = 15,9910 m

l = 15,9910 m

t = 5,3303 m

Spesifikasi :

Fungsi : Untuk menyimpan $(NH_4)_2SO_4$ untuk sementara waktu sebelum diproses

Bentuk : Bangun segiempat

Kapasitas = 1363,029999 kg

Waktu penyimpanan = 30 hari

Dasar pemilihan = Sesuai dengan bahan solid

Ukuran bangunan = p = 15,9910 m

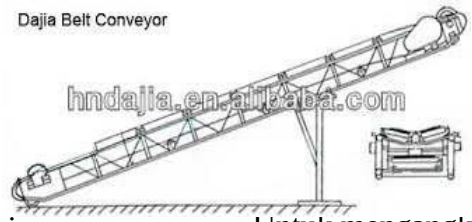
l = 15,9910 m

t = 5,3303 m

Bahan kontruksi = Beton

Jumlah = 1

12. BELT CONVEYOR (J-131)



Fungsi : Untuk mengangkut $(NH_4)_2SO_4$ dari gudang

Type : Troughed belt on 45^o idlers with rolls of equal length

Dasar pemilihan : Dipilih conveyor jenis belt sesuai dengan bahan

Perhitungan :

Rate massa = 2677,5761 kg/jam

= 2,6776 ton/jam

Kapasitas = 2,6776 ton/jam

dipilih belt conveyor dengan spesifikasi sebagai beriku Perry ed 7 Tabel 21-7

Kapasitas maksimum	:	32	ton/jam
Belt width	:	14	in
Belt speed	:	100	ft/min
hp/10 ft, lift	:	0,34	hp/ft
Through width	:	9	in
Skirt seal	:	2	in

asumsi : jarak belt conveyor ke cutter = 50 ft

tinggi belt ke cutter = 10 ft

slope = α

$$\text{tg } \alpha = \frac{10}{50} = 0{,}2$$

$$\alpha = 11{,}31^{o}$$

Panjang belt = $\sqrt{(10^2 + 50^2)}$ = 50,9902 ft

Perhitungan power :

hp/10 ft, lift = 0,34 hp/ft

$$\text{hp} = \frac{50{,}9902}{10} \times 0{,}34 = 1{,}7337$$

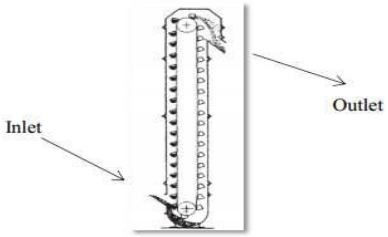
Penambahan power untuk tripper = 2 hp

Power total = 3,7337 hp

Spesifikasi :

Fungsi	:	Untuk mengangkut $(NH_4)_2SO_4$ dari gudang ke bucket elevator
Type	:	Troughed belt on 45° idlers with rolls of equal leng
Kapasitas maksimum	:	32 ton/jam
Dasar pemilihan	:	Sesuai untuk bahan solid
Belt width	:	14 in
Belt speed	:	100 ft/min
Trough width	:	9 in
Skirt seal	:	2 in
Panjang	:	50,9902 ft
Sudut elevansi	:	11,31 °
Power	:	3,73367 hp
Jumlah	:	1 buah

13. BUCKET ELEVATOR (J-132)



Fungsi : Untuk mengangkut amonium sulfat dari belt conveyor ke hopper
Type : Centrifugal discharge elevator
Bahan : Carbon Steel
Perhitungan :
Rate massa = 2677,5761 kg/jam
= 5903,037805 lb/jam
ρ bahan = 110,3059896 lb/cuft
Data dari Perry ed 7 Tabel 21-8
Tinggi bucket = 50 ft
Putaran poros = 43 rpm

Untuk kapasitas maksimum = 14 ɔn/jam → Kecepatan buket elevator sebesar 225 ft/menit

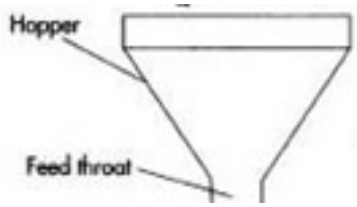
Sehingga untuk kapasitas maka, = 2,6776 ton/jam

Kecepatan bucket elevator = $\frac{2,6776}{14}$ x 225
= 43,0325 ft/menit
Power pada head shaft = 1,6 hp
Power tambahan = 2% hp tiap ft
= 0,02 hp/ft x 50 ft
= 1 hp
P total = 1,6 + 1
= 2,6
Ukuran Bucket = 6" x 4" x 4,25"
Bucket spacing = 12 in
Efisiensi motor = 80%
Maka motor penggerak yang digunakan = $\frac{2,6}{0,8}$
= 3,25 hp

Spesifikasi :
Fungsi : Untuk mengangkut $(NH_4)_2SO_4$ dari belt conveyor ke hopper
Type : Continous discharge bucket elevator
Dasar pemilihan : Dapat memindahkan bahan dengan ketinggian tertentu

Kapasitas	:	2,6776	ton/jam
Tinggi Bucket	:	50 ft	
Kecepatan Bucket	:	43,0325	ft/menit
Bucket Spasing	:	12 in	
Ukuran Bucket	:	6" x 4" x 4,25"	
Putaran head shaft	:	43 rpm	
Lebar belt	:	7 in	
Power	:	3,25 hp	
Jumlah	:	1 buah	

14. HOPPER AMMONIUM SULFAT (F-133)



Fungsi : Menampung sementara amonium sulfat sebelum masuk tangki pelarutan

Type : Silinder dengan tutup bawah berbentuk konical dengan posisi vertikal

Komposisi bahan :

Bahan Masuk

Komponen	Berat	Fraksi berat	ρ (gr/cm)
$(NH_4)_2SO_4$	2672,5691	0,9981	1,769
H_2SO_4	0,7229	0,0003	1,97
H_2O	4,2841	0,0016	1
Total	2677,576093	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0,9981}{1,769} + \frac{0,0003}{1,97} + \frac{0,0016}{1}} \times 62,43$$

$$= 110,3060 \text{ lb/cuft}$$

Rate Massa = 2677,576093 kg/jam

= 5904,055284 lb/jam

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

$$= \frac{5904,055284 \text{ lb/jam}}{110,3060 \text{ lb/cuft}}$$
$$= 53,5243 \text{ cuft/jam}$$

Perancanaan Dimensi Hopper

Asumsi waktu tinggal hopper = 2 jam
Bahan masuk = 5904,055284 lb/jam
Volume bahan = 53,5243 cuft/jam x 2
= 107,0486799 cuft
ρ campuran = 110,3060 lb/cuft

Asumsi volume bahan mengisi 80% volume tangki sehingga volume ruang kosong sebesar 20% dan digunakan 1 buah tangki

Volume tangki $= \frac{107,0486799}{0,8}$
= 133,8108499 cuft
Safety factor = 10%
Volume tangki = 133,8108499 x 1,1
= 147,1919

Menentukan ukuran Hopper dan ketebalannya

Tinggi conical :

$H = \frac{tg\ \alpha \times (D - m)}{2}$ (Hesse : 92 pers 4-17)

Keterangan :
α = sudut conis : 30^o
D = diameter tangki : ft
m = flat spot center : 12 in → 1 ft

Ditentukan :
Diameter atas = 3,5 ft
maka,

$H = \frac{tg\ \alpha \times (D - m)}{2}$
$= \frac{0,577 \times (3,5 - 1)}{2}$ (Hesse: 92 pers 4-17)
= 0,7213 ft

Volume conical = 0,262 h ($D^2 + D \cdot m + m^2$)
= 0,262 x 0,7213 x 15,75
= 2,9762 cuft

Volume shell = 147,1919 - 2,9762
= 144,2157 cuft

Volume shell = 3,14 . D^2 . H/4
144,2157 = 3,14 . D^2 . H/4
H = 14,9971

Jadi tinggi total = 0,7213 + 14,9971
= 15,7183 ft

$$\text{Tekanan bahan} = \frac{\text{Density . H}}{144} = \frac{110,3060 \times 15,7183}{144} = 12,0405 \text{ psig}$$

P oprasi = 14,7 psi

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

P design = 1,1 x P perencanaan
= 1,1 x (14,7 + 12,0405)
= 29,4145 psig

Menentukan tebal minimum shell :

$$t_{min} = \frac{P \times ri}{fe - 0,6P} + C$$ (Brownell : Pers 13-1)

dengan :

t_{min} = tebal shell minimum ; in
P = tekanan tangki ; psi
ri = jari0jari tangki ; in (1/2 D)
C = faktor korosi ; in (1/8 in)
E = faktor pengelasan, digunakan dobel welded
e = 0,8 (Brownell : 13-2)
f = stress allowable, bahan konstruksi carbon steel SA-283 grade C, maka : f = 12650 (Brownell : 13-1)

r = 1/2 x 3,5
= 1,75 ft
= 21 in

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

$$= \frac{29,41450604 \times 21}{10120 - 17,64870362} + 0,125$$

= 0,1861 + 0,125
= 0,3111 in → digunakan t = 5/16 in

Penentuan tebal head
Jenis : Conical
Type las : Double welded butt joint effisiensi 80%
(Brownell : 13-2)

Tebal tutup :

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

$$= \frac{29{,}415 \times 21}{2\cos 24\,(12650 \times 0{,}8 - 1 \times 29{,}415)} + 0{,}125$$

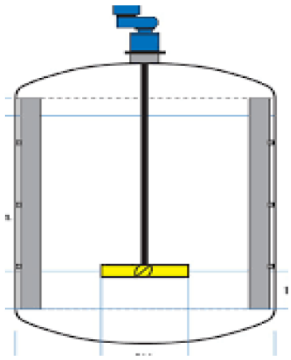
= 0,197074099 in → 3/16 in

Spesifikasi hopper :

Fungsi : Menampung sementara $(NH_4)_2SO_4$ sebelum masuk tangki pelarutan
Type : Silinder dengan tutup bawah berbentuk conical dengan posisi vertikal

Kapasitas	:	107,0486799	cuft
Diameter dalam silinder	:	3,5	ft
Tinggi silinder	:	14,99708272	ft
Tebal shell	:	0,3125	in
Diameter atas conical	:	3,5	ft
Diameter bawah conical	:	1	ft
Tinggi conical	:	0,7213	ft
Cone angle	:	30	o
Tebal angle	:	0,1875	in
Jumlah	:	1 buah	

15. TANGKI PELARUT AMMONIUM SULFAT (M-140)



Fungsi : Melarutkan $(NH_4)_2SO_4$ dengan air proses

Type : Silinder tegak, tutup atas dished, tutup bawah conis dilengkapi pengaduk

Kondisi oprasi :

Tekanan oprasi = 1 atm (tekanan atmosfer)

Suhu oprasi = 30 ^oC (suhu kamar)

Waktu tinggal = 60 menit

Dimensi ratio, H/D

ditetapkan ⟶ H = 2 D

Perhitungan :

Komposisi bahan masuk

Komponen	Berat	Fraksi berat	ρ (gr/cm^3)
$(NH_4)_2SO_4$	2672,5691	0,9981	1,769
H_2SO_4	0,7229	0,0003	1,97
H_2O	4,2841	0,0016	1
Total	2677,576	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}9981}{1{,}769} + \frac{0{,}0003}{1{,}97} + \frac{0{,}0016}{1}} \times 62{,}43$$

$$= 110{,}3060 \text{ lb/cuft}$$

a. Penentuan Volume Tangki

Densitas campuran = 110,3060 lb/cuft

Rate Produk = 2677,576 kg/jam

= 5903,038 lb/jam

ρ campuran = ρ bahan

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

$$= \frac{5903{,}038 \text{ lb/jam}}{110{,}3060 \text{ lb/cuft}}$$

$$= 53{,}5151158 \text{ cuft/jam}$$

2. Feed air proses dari utilitas

Rate Produk = 3426,371 kg/jam

= 7553,845 lb/jam

ρ air = 62,43 lb/cuft

$$\text{Rate volumetrik} = \frac{\text{rate massa}}{\text{densitas}}$$

$$= \frac{7553,845 \text{ lb/jam}}{62,4300 \text{ lb/cuft}}$$

= 120,9970395 cuft/jam

Total rate volumetrik = 53,5151158 + 120,997039

= 174,5121553 cuft/jam

Perhitungan :

Komposisi bahan :

Bahan Masuk

Komponen	Berat	Fraksi berat	ρ (gr/cm^3)
$(NH_4)_2SO_4$	2672,5691	0,4378	1,769
H_2SO_4	0,7229	0,0001	1,97
H_2O	3430,6547	0,5620	1
Total	6103,947	1	

$$\rho \text{ campuran} = \frac{1}{\frac{0,4378}{1,769} + \frac{0,0001}{1,97} + \frac{0,5620}{1}} \times 62,43$$

= 77,1114 lb/cuft

a. Penentuan Volume Tangki

Densitas campuran = 77,1114 lb/cuft

Rate Produk = 6103,947 kg/jam

= 13456,883 lb/jam

ρ campuran = ρ bahan

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

$$= \frac{13456,883 \text{ lb/jam}}{77,1114 \text{ lb/cuft}}$$

= 174,5121553 cuft/jam

Direncanakan waktu oprasi sel 1 jam dengan 1 buah tangki, sehingga :

Volume Bahan = 174,5121553 x 1

= 174,5121553 cuft

Volume bahan mengisi 80% volume tangki, sehingga volume tangki :

$$\text{Volume Tangki} = \frac{174,5121553}{0,8}$$

$= \quad 218{,}1402 \quad cuft$

$V_s = (\pi/4) \times Ds^2 \times Hs$

$= (\pi/4) \times Ds^3 \times 2$

$= 1{,}5714 \quad Ds^3$

$V_{tutup\ atas} = 0{,}000049 \quad Ds^3$ (Brownell : 88)

$V_{tutup\ bawah} = (\pi\ Ds^3) / 24\ tg\alpha$ (Hesse, 1962)

$$= \frac{3{,}14 \times Ds^3}{24 \times tg\ 30^o}$$

$= 0{,}2266$

$V_t = V_s + V_{tutup\ atas} + V_{tutup\ bawah}$

$218{,}1402 = 1{,}5714\ Ds^3 + 0{,}000049\ Ds^3 + 0{,}2266\ Ds^3$

$218{,}1402 = 1{,}7981\ Ds^3$

$D = 4{,}9504$ ft

≈ 5 ft $= 60$ in

$H = 9{,}9008$ ft

≈ 10 ft $= 120$ in

b. Tebal Shell

Tinggi liquid dalam shell :

Volume liquid $= V_s + V_{alas}$

$174{,}5122 = (\pi/4) \times h \times Ds^2 + 0{,}2266\ Ds^3$

$174{,}5122 = 0{,}785 \times h \times 25 + 0{,}2266 \times 125$

$h = 7{,}4490$ ft

$= 2{,}2719$ m

c. Menentukan Tekanan Design

$P_{oprasi} = 1$ atm $\longrightarrow$ $14{,}7$ psi

$P_{hidrostatis} = \rho \times (g / gc) \times h$

$$= \frac{77{,}1114 \times 1 \times 7{,}4490}{144}$$

$= 3{,}9889$ psi

$P_{design} = (P_{oprasi} + P_{hidrostatis}) \times 1{,}1$

$= (14{,}7 + 3{,}9889) \times 1{,}1$

$= 20{,}5578$ psi

Dipergunakan bahan konstruksi yang terbuat dari Carbon Steel dengan spesifikasi SA 283 grade C

$f_{allowable} = 12650$ (Brownell : T13.1)

C = 0,125 in

Sambungan las dengan type double welded butt joint

Efisiensi las, E = 0,8

r = 1/2 x 60

= 30 in

Rumus tebal shell yang digunakan adalah :

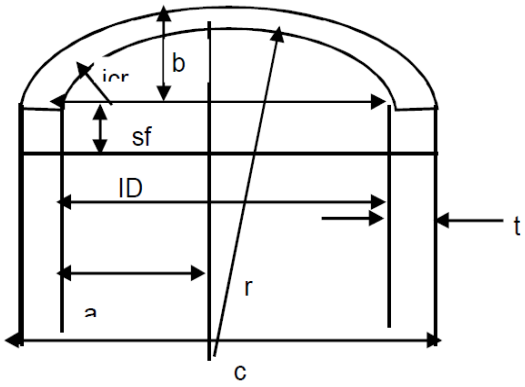
$$t_{min} = \frac{P \times ri}{fe - 0{,}6P} + C \qquad \text{(Brownell : Pers 13-1)}$$

$$= \frac{20{,}5578 \times 30}{((12650 \times 0{,}8) - (0{,}6 \times 20{,}558))} + 1/8$$

= 0,1860 in

Diambil tebal shell = 3/16 in

Penentuan dimensi tutup atas, dished



Tutup atas berbentuk standart dished

OD = ID + 2ts

= 5 + 2 x 3/16

= 5 3/8 ft

= 64,5 in

OD = rc

rc = 64,5 in

= 5,375 ft

Tinggi tutup (h) = $rc - (rc^2 - (D^2/4))^{0,5}$ (Hesse, 1962)

= $5\ 3/8 - (28\ 8/9 - 6{,}25)^{0,5}$

= 0,6168 ft

Volume dishead = $1{,}1 \times h^2 (3rc - h)$

= $1{,}1 \times 0{,}3804 \times (3 \times 5\ 3/8 - 0{,}6168)$

= 6,4896 cuft

Bentuk : Flanged and standart dishead head

Tebal standart toripherical dished (atas)

$$t = \frac{0{,}885 \times P_d \times r_c}{(f \times E - 0{,}1P_d)} + C \qquad \text{(Brownell : 13-12)}$$

Dimana :

P_d = Tekanan desain (psi)

r_c = Diameter luar (in)

E = Faktor Pengelasan 80%

t = Tebal dinding minimal (in)

$$t = \frac{0{,}885 \times 20{,}558 \times 64\ 1/2}{(12650 \times 0{,}8) - (0{,}1 \times 20{,}558)} + 0{,}125$$

t = 0,2410 in

Diambil tebal head sebesar 0,2500 in atau 4/16 in

Tutup bawah berbentuk conical

$$h = \frac{tg\alpha \times (D - m)}{2} \qquad \text{(Hesse, 1962)}$$

Dimana :

D : Diameter bejana (ft)

tgα : Sudut Conis 30°

m : 12" = 1 ft

$$h = \frac{tg\ 30^o \times (5 - 1)}{2}$$

h = 1,1547 ft

Volume conical = $0{,}262\ h\ (D^2 + D\ m + m^2)$

= 0,262 x 1,1547 x 31

= 9,3785 cuft

Bentuk : Standart conical dished

$$t = \frac{P_d \times r_c}{2 \cos 60\ (f E - 0{,}6P_d)} + C \qquad \text{(Brownell; 259)}$$

Dimana :

P_d = Tekanan desain (psi)

E = Faktor pengelasan 80%

t = Tebal dinding minimal (in)

$$t = \frac{20{,}5578 \times 64\ 1/2)}{2 \cos 30\ ((12650\ 0{,}8) - (1 \times 20{,}558)} + 1/8$$

t = 0,5502 in

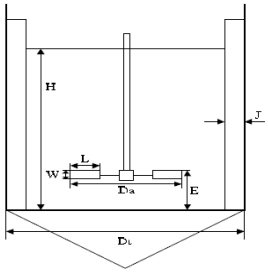
Diambil tebal head $\frac{9}{16}$ in

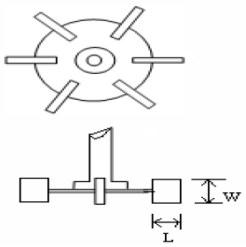
Sistem Pengaduk

Dipilih pengaduk type flat blade turbine dengan jumlah blade 6

1. Penentuan Dimensi Pengaduk

Tinggi bahan total	H_L	=	7,4490	=	89,3876	in
Diameter dalam tangki	D_t	=	5	=	60	in





Ukuran pengaduk diambil dari (Mc. Cabe: 247)

$\frac{Da}{Dt} = \frac{1}{3}$ $\quad\quad$ $\frac{E}{Da} = 1$

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

$\frac{W}{Da} = \frac{1}{5}$

meter impeler (Da) = 1/3 diameter s = $\frac{1}{3}$ x 5 = 1,6667 ft

ebar blade (w) = 1/5 diameter impell = $\frac{1}{5}$ x 1,7 = 0,3333 ft

njang blade (L) = 1/4 diameter impe = $\frac{1}{4}$ x 1,7 = 0,4167 ft

k impeler dari dasar (E) = 1/3 diameter s = $\frac{1}{3}$ x 5 = 1,6667 ft

Lebar baffle (J) = 1/12 diameter shel = $\frac{1}{12}$ x 5 = 0,4167 ft

Tebal pengaduk = $\frac{1}{10}$ x 0,4167 = 0 ft = 0,5 in

Keterangan :

Da	=	Diameter pengaduk
Dt	=	Dimeter tangki
L	=	Panjang blade
W	=	Lebar blade
E	=	Jarak pengaduk dari dasar tangki
J	=	Lebar baffle

2. Penentuan Jumlah Pengaduk

Tinggi bahan total H_L = 7,4490 ft

Diameter dalam tangki D_t = 5 ft

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

$$= \frac{77,1114 \text{ lb/cuft}}{62,303 \text{ lb/cuft}}$$

$$= 1,2377$$

$$\text{Jumlah impeler} = \frac{\text{tinggi larutan}}{\text{diameter bejana}} \times sg$$

$$= \frac{7,4490}{5} \times 1,2377$$

$$= 1,8439$$

Jadi jumlah impeler sebanyak = 4 buah

3. Penentuan Power Motor

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

$$= \frac{1,2377 \times 0,001}{0,996}$$

= 0,0012 lb/ft dt (berdasarkan sg bahan)

ρ campuran = 77,1114 lb/cuft

Kecepatan putaran pengadukan jenis turbin antara 200-250 m.min)

Ditetapkan kecepatan pengaduk,N = 150 rpm = 2,5 rps

Putaran pengaduk, V = π x N x Da (Joshi: 389)

= π x 150 x (1,6667 x 1/3

= 261,9048 m/min (memenuhi)

Bilangan Reynolds (Nre)

$$Nre = \frac{\rho \times D^2 \times N}{\mu} = \frac{77,1114 \times 2,7778 \times 2,5}{0,0012}$$

= 430929,0833 (aliran trubulen)

Perhitungan power pengaduk yang dibutuhkan :

Diperoleh nilai Nre > 10000, sehingga Np = K_T

K_T = Np = 1,2 (Ludwig, Fig 5-13)

$$P = \frac{K_T N^3 Da^5 \rho}{gc}$$ (Mc Cabe : 257 Pers 9.12b)

$$P = \frac{1,2 \times 15,625 \times 12,8601 \times 77,1114}{32,17}$$

= 577,9799231 ft.lbf/s

= 577,9799231 / 550
= 1,0509 hp

(Joshi, 1981)

Power Losses pada Gland 10% hp = 0,1 x 1,0509
= 0,1051 hp

Diambil power = 0,2 hp

Power input dengan gland losses = 1,0509 + 0,1051
= 1,1560 hp

Transmission sistem losses 20% = 0,2 x 1,1560
= 0,2312 hp

Power total = 1,1560 + 0,2312
= 1,3872 hp

Karena jumlah pengaduk 2 buah, maka power = 2 x 1,3872
= 2,7743 hp

Efesiensi motor = 85%

Sehingga power motor = $\frac{2,7743}{0,85}$

= 3,263886624 hp ≈ 3 hp

Spesifikasi :

Dimensi Shell :

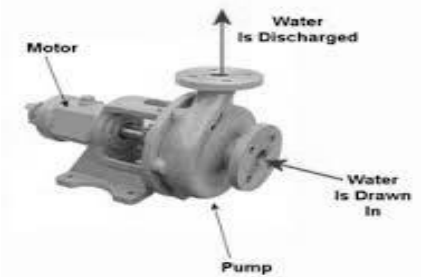
Diameter shell, inside	:	5	ft
Tinggi Shell	:	10	ft
Tebal Shell	:	0,1875	in
Tebal tutup (dished)	:	0,25	in
Tebal tutup (conical)	:	0,5625	in

Sistem pengaduk

Dipakai impeler jenis turbin dengan 6 buah flat blade dengan 2 impeller

Diameter impeller	:	1,6667	ft
Panjang blade	:	0,4167	ft
Lebar Blade	:	0,3333	ft
Power motor	:	3	hp
Bahan konstruksi	:	Carbon steel SA-283 grade C	
Jumlah tangki	:	1 buah	

16. POMPA -3 (L-141)



Fungsi = Memindahkan bahan dari mixing 2 ke heater
Type = Centrifugal Pump
Dasar pemilihan = Sesuai untuk viskositas <10 cP dan bahan liquid

Perhitungan : (Asumsi aliran turbulen)
Data perhitungan :
Rate bahan = 6103,947 kg/jam
= 13456,883 lb/jam
ρ campuran = 77,1114 lb/cuft
= 1,2353 gr/ml

$$\text{Rate volumetrik} = \frac{\text{rate massa}}{\rho \text{ campuran}} \times \text{waktu tinggal}$$

$$= \frac{13456{,}883 \text{ lb/jam}}{77{,}1114 \text{ lb/cuft}}$$

= 174,5121553 cuft/jam
= 2,9085 cuft/menit
= 21,7574 gpm

Perhitungan diameter pipa
Asumsi aliran Turbulen :
Diameter optimum untuk turbulen, Nre >4000 digunakan persamaan :
Di optimum = $3.9 \times qr^{0,45} \times \rho^{0,13}$ (Peters, ed.4 pers.15 hal 496)
Dengan : qr = Fluid flow rate , ρ = fluid density ; lb cuft
qr = 2,9085 cuft/menit
= 0,04848 cuft/s
Diameter pipa optimum = $3.9 \times qr^{0,45} \times \rho^{0,13}$ (Peters, ed.4 pers.15 hal 496)
= 1,7574 in
Dipilih pipa 2 in, sch 160 (Brownell & Young,1987)
OD = 2,375 in 0,19792 ft
ID = 1,689 in 0,14075 ft

Luas , A = $(1/4.\ \pi.\ ID^2)$
= 0,0156 ft^2

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

$$= \frac{77{,}1114 \text{ lb/cuft}}{62{,}303 \text{ lb/cuft}} \times 0{,}996$$

= 1,2327

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

$$= \frac{1{,}2327 \times 0{,}001}{0{,}996}$$

= 0,0012 lb/ft s (berdasarkan sg bahan)

= 1,8419 cp

Kecepatan aliran (V) = $\frac{\text{Rate volumetrik}\quad \text{cuft/dt}}{\text{Luas, A}\quad \text{ft}^2}$

= 3,1171 ft/dt

$$\text{Nre} = \frac{D\,V\,\rho}{\mu} = \frac{0{,}14075 \times 3{,}1171 \times 77{,}1114}{0{,}0012}$$

= 27334,6854 > 4000 (asumsi turbulen benar)

Menentukan jumlah energi yang hilang

1. Karena pipa lurus

Ditetapkan :

Panjang pipa lurus = 15 ft

Dipilih pipa Galvanized iron = 0,00015 (Geankoplis: 88)

maka harga e/D = 0,002

f = 0,007 (Geankoplis: 88)

gc = 32,174 ft.lbm/dt².lbf

2. Karena friksi (Geankoplis: 88)

Taksiran panjang pipa lurus = 15 ft

4 elbow 90° = 4 x 35 x ID pipa = 19,705 ft

1 gate valve = 1 x 90 x ID pipa = 12,6675 ft +

Panjang total pipa = 47,3725 ft

Friksi yang terjadi :

1. Friksi karena gesekan bahan dalam pipa :

$$F1 = (2f \times V^2 \times Le)/(gc \times D) = 1{,}42303 \ \frac{\text{ft. lbf}}{\text{lbm}}$$

2. Friksi karena kontraksi dari tangki ke pipa:

$$F2 = (K \times V2^2)/(2 \times \alpha \times gc) = 0{,}00755 \ \frac{\text{ft. lbf}}{\text{lbm}}$$ (α= 1 untuk aliran turbulen)

(K= 0,05 A tangki >>>Apipa)

3. Friksi karena ekspansi dari pipa ke tangki: (Peters ed.4 hal 484)

$$F_3 = \frac{V^2}{2 \times \alpha \times gc} = \frac{\Delta V_2^{\,2} - \Delta V_1^{\,2}}{2 \times \alpha \times gc} = 0{,}151 \ \frac{\text{ft. lbf}}{\text{lbm}}$$

(V_1 <<<< V_2, maka V_1 dianggap = 0)

4. Friksi karena Elbow 90^o

$$F_4 = \frac{K_f \times V_1^2}{2} = \frac{0{,}75 \times 9{,}717}{2} = 3{,}6437$$

5. Friksi karena Gate Valve

$$F_5 = \frac{K_f \times V_1^2}{2} = \frac{0{,}17 \times 9{,}717}{2} = 0{,}8259$$

ΣF(Total Friksi)

$$= F_1 + F_2 + F_3 + F_4 + F_5$$
$$= 1{,}4230 + 0{,}0076 + 0{,}1510 + 3{,}644 + 0{,}8259$$
$$= 6{,}0512 \ \frac{ft.lb_f}{lb_m}$$

Persamaan Bernoulli :

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

$P_1 = P_{hidrostatis}$

Diketahui data dari tangki pelarut 2

Tinggi bahan = 7,4490 ft (Tangki mixing)

ρ bahan = 77,1114 lb/cuft

$P_{hidrostatis} = \rho \cdot H = 77{,}1114 \times 7{,}4490 = 574{,}4002719\ lb/ft^2$

$P_2 = 1\ atm = 14{,}7\ psi = 14{,}7 \times 144 = 2116{,}8000\ lbf/ft^2$

$\Delta P = P_2 - P_1 = 2116{,}80 - 574{,}4 = 1542{,}3997\ lb_f/ft^2$

$$\frac{\Delta P}{\rho} = \frac{1542{,}3997\ lb_f/ft^2}{77{,}1114\ lb_m/ft^3} = 20{,}0022\ \frac{ft.lb_f}{}$$

= 20,0022 lb_m

Energi Potensial

Z_2 = 13 ft (Reaktor)

Z_1 = 7,449 ft

Asumsi : g/gc = 1

g percepatan gravitasi = 32 ft/dt^2

gc konstanta gravitasi = 32 ft/dt^2 x lb_m/lb_f

$$\Delta Z \frac{g}{gc} = 5{,}5510 \text{ ft} \times \frac{32 \text{ ft/dt}^2}{32 \text{ ft.lb}_m/\text{dt}^2.\text{lb}_f}$$

$$= 5{,}5510 \frac{\text{ft . Lbf}}{\text{lbm}}$$

Energi Kinetik

$$\frac{\Delta V^2}{2 \times gc \times \alpha} = \frac{9{,}7166}{2 \times 32{,}2 \times 1}$$

$$= 0{,}1509 \frac{\text{ft.lb}_f}{\text{lb}_m}$$

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

$$= 20{,}00 + 5{,}5510 + 0{,}1509 + 6{,}051$$

$$= 31{,}7553 \frac{\text{ft.lb}_f}{\text{lb}_m}$$

$$hp = \frac{Wf \times qr \times \rho}{550}$$

$$= \frac{31{,}76 \times 0{,}0485 \times 77{,}1114}{550}$$

$$= 0{,}2158 \text{ hp}$$

Effisiensi pompa = 8% (Peters & Timmerhaus, 2003)

$$Bhp = \frac{hp}{\eta \text{ motor}} = \frac{0{,}2158}{0{,}08} = 2{,}69777719 \text{ hp}$$

Effisiensi motor = 82% (Peters & Timmerhaus : fig 14-36)

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

$$= \frac{2{,}70}{82\%}$$

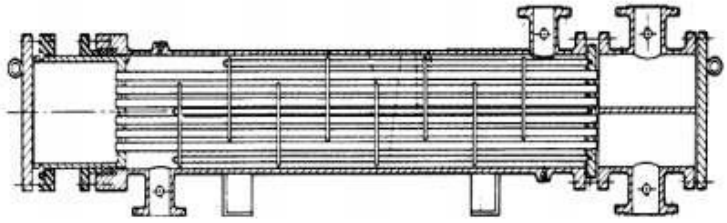
= 3,3102 hp

digunakan power = 3,5 hp

Spesifikasi :

Fungsi	=	Memindahkan bahan dari mixing 2 ke heater
Jenis	=	Pompa centrifugal
Kapasitas	=	6103,947 kg/j
Power	=	3,5 hp
eff. Pompa	=	8%
eff. Motor	=	82%
Jumlah	=	1 pompa
Bahan kontruksi	=	Carbon Stell

17. HEATER -2 (E-142)

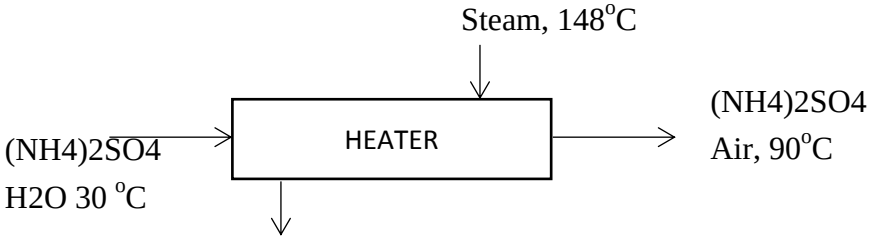


Fungsi : Memanaskan bahan (NH4)2SO4 dari 30 ^{o}C menjadi 90 ^{o}C

Tipe : 1-2 *Shell and tube heat exchanger (Fixed tube)*

Dasar Pemilihan : Umum digunakan pada kapasitas yang besar

Kondisi Operasi :
- Tekanan = 1 atm
- Temperatur = 90 ^{o}C
- Waktu proses : *Continue*



Kondisi Proses :

- **Fluida Dingin**

T masuk (t_1) = 30 ^{o}C = 86,000 ^{o}F = 303,15 K

T keluar (t_2) = 90 ^{o}C = 194 ^{o}F = 363,15 K

P masuk = 1 atm = 14,700 psia

P keluar = 1 atm = 14,700 psia

- **Fluida Panas**

T masuk (T_1) = 148 ^oC = 298,40 ^oF = 421,15 K

T keluar (T_2) = 148 ^oC = 298,40 ^oF = 421,15 K

P masuk = 4,5 atm = 66,150 psia

P keluar = 4,5 atm = 66,150 psia

Fluida dingin (^oF)		Fluida panas (^oF)	diff
194,00	Higher Temp	298,40	104,40
86,00	Lower Temp	298,40	212,40
108,00	diff	0	108,00

Perhitungan :

1. Data dari neraca Massa dan neraca panas diperoleh :

Panas yang dibutuhkan; Q = 282674,5940 kkal/jam

= 1121087,4400 Btu/jam

Steam yang digunakan : W_{steam} = 558,3872 kg/jam

= 1231,0316 lb/jam

Wbahan = 6103,9467 kg/jam

= 13456,8830 lb/jam

2. Log Mean Temperature Difference :

Δt_1 = 298,40 - 194,00 = 104,4 ˚F

Δt_2 = 298,40 - 86,000 = 212,4 ˚F

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

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

= 152,1 ˚F

$$R = \frac{T1 - T2}{t2 - t1} = \frac{298,40 - 298,40}{194 - 86}$$

= 0,0000

$$S = \frac{t2 - t1}{T1 - t1} = \frac{194 - 86}{298 - 86}$$

= 0,508

F_T = 0,75 **(Kern fig 18)**

(untuk 1-2 shell and tube)

$\Delta T = F_T \times LMTD$

$= 0{,}75 \times 152{,}0609$

$= 114{,}0457 \ ^{\circ}F$

3. Tc dan tc

Tc = Tav steam

$$Tc = \frac{T_1 + T_2}{2} = \frac{298{,}40 + 298{,}40}{2}$$

$= 298{,}40 \ ^{o}F \quad (\mu = 0{,}015 \ cp)$

tc = tcav bahan

$$tc = \frac{t_1 + t_2}{2} = \frac{86{,}00 + 194{,}00}{2}$$

$= 140{,}00 \ ^{o}F \quad (\mu = 1{,}85 \ cp)$

Trial Ud

Hot Fluid = Steam

cold Fluid = water

Ud = 200-700 Btu/ft^{2}j^{o}F **(tabel 8 Kern hal.840)**

Dipilih Ud = 200 Btu/ft^{2}j^{o}F

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

$$= \frac{1121087{,}4400}{200 \times 114{,}05}$$

$= 49{,}1508 \ ft^2$

Direncanakan dengan spesifikasi

Digunakan tube dengan ukuran :

OD, BWG = 3/4 in , 12 BWG

Pitch = 1 in square pitch

Panjang Tube L = 6 ft

Dari kern tabel 10 hal 843 diperoleh :

ID = 0,532 in

a't flow area per tube = 0,223 in^2

a'' surface per lin = 0,1963 ft^2

Jumlah Tube Nt $= \frac{A}{a'' \times L} = \frac{49,151}{0,1963 \times 6} = 41,73$ buah

digunakan Nt = 40 buah

Dari Kern, tabel 9 hal 842, untuk 3/4 in 12 BWG 1 square pitch ;

Tube passes = 4

didapatkan :

ID Shell = 10 in (tabel 9, Kern)

pitch = 1 in square

Fluida Panas (Tube side) Steam	Fluida dingin (Shell side)
4. Flow area (a_b)	**4**. Flow area (a_s)
$a_t = \frac{Nt \times a'_t}{144 \quad n}$	$a_s = \frac{ID \cdot C' \cdot B}{144 \quad P_T}$
	ID = 10 in
Kern, tabel 10	asumsi : B = ID / 5
3/4 OD 12 BWG	= 2 in
a'_t = 0,223 in^2 (tabel 10)	P_T = 1
$a_t = \frac{40 \times 0,22}{144 \times 4}$	C' = P_T - OD tube
	= 1 - 3/4
= 0,0155 ft^2	= 0,25
	$a_s = \frac{10 \times 0,25 \times 2,0}{144 \times 1}$
	= 0,0347 ft^2
5. Kecepatan massa (G_t)	**5**. Kecepatan massa (G_s)
$G_t = \frac{W}{a_t}$	$G_s = \frac{W}{a_s}$
Wsteam = 1231,03 lb	W fluida = 13456,8830 kg
$G_t = \frac{1231,03}{0,015}$	$G_s = \frac{13456,8830}{0,0347}$
= 79492,625 lb / jam ft^2	= 387558,2298 lb / jam ft^2
	tc = 140 ^oF
	μ = 1,849 cps
6. pada T_c = 298 ^oF	= 4,4752 lb / jam.ft

μ = 0,015 cps
= 0,0363 lb / jam.ft

D_i = 0,53 in (Kern,Tabel 10)
= 0,0443 ft

$$Re_t = \frac{D_i \times G_t}{\mu}$$

$$= \frac{0,0443 \times 79492,625}{0,0363}$$

= 97084,6569

De' = 0,95 in Kern, fig. 28
= 0,0792 ft

$$Re_s = \frac{D_e \times G_s}{\mu}$$

$$= \frac{0,0792 \times 387558,2298}{4,4752}$$

= 6855,8719

7. j_H = 45 (fig. 24)

8. pada t_c = 140 ^oF

Cp = 0,9500 Btu / lb.^oF (fig 2)

k = 1 Btu/jam ft^{2o}F (tabel 4)

$$\left(\frac{Cp.\mu}{k}\right)^{1/3} = \frac{1,0 \times 4,4752}{0,8}$$

= 1,7451

μw = 1 (standart)

$\varphi t = (\mu/\mu w)^{0,14}$

= 1,233

9. Hio untuk kondensasi steam

hio = 1500 Btu/j ft^2 ^oF (Kern;168)

9'. ho

$$ho = J_H \frac{k}{De} \left(\frac{Cp.\mu}{k}\right)^{1/3} \varphi t$$

$$= 45 \frac{0,8}{0,0792} 1,7451 \quad 1,233$$

= 978,794 Btu/hr.ft^2.^oF

10. U_C

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

$$= \frac{1500 \times 978,7938}{1500 + 978,7938}$$

= 592,3005 BTU/j ft^2 F

11. U_D

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

$$= \frac{1121087,440}{49,151 \times 114,046}$$

= 200,000 BTU/j ft^2 F

Rd hitung $= \frac{U_C - U_D}{U_C \times U_D}$

$= \frac{592,30 - 200,000}{592,30 \times 200,000}$

$= 0,0033$ J ft^2 F/BTU

Rd perthitungan > Rd data (Kern : T 12)

0,0033 > 0,003 untuk media air

Pressure Drop

Tube Side Bahan	Shell side Steam
1. $Re_t = 97084,657$	1'. $Re_s = 6855,87$
$f = 0,00015$ ft^2/in^2 *(Kern,Fig 26)*	$f = 0,003$ ft^2/in^2 *(Kern,Fig 29)*
$v = 6,2$ cuft/lb (Kern, Fig 6)	$s = 1,201$
$s = \frac{1,85}{62,5}$	$De' = \frac{4 \times a_s}{(N_t \times \pi \times (0,75/12)) + \pi}$
$= 0,0296$	$= \frac{4 \quad 0,035}{40 \quad 3,14 \quad 0,063 + 3,14}$
	$= 0,013$ ft
	No. of crosses, (N+1)
2. $\Delta P_t = \frac{f.Gt^2.L.n}{5,22.10^{10}.De.s\,\varphi s}$	2'. $N+1 = 12\ L / B$
	$= 12 \quad 6 \quad / \quad 2$
$\frac{0,0002 \quad 79493 \quad 6,000 \quad 2,0}{5,22.10^{10} \quad 0,044 \quad 0 \quad 1}$	$= 36$
	$D_s = 10,000 \quad / \quad 12$
$= 0,1661$ psi	$= 0,833$ ft
	$s = 1,0$ (Tabel 6)
3. $Gt = 79492,6$ lb/j ft^2	3'. $\Delta P_s = \frac{f.Gs^2.Ds.(N+1)}{5,22.10^{10}.De.s.\varphi s}$
$\frac{V^2}{2g'} = 0,001$ (Kern, fig 27)	$= \frac{0,003 \quad 387558 \quad 0,833 \quad 36,0}{5,22.10^{10} \quad 0,079 \quad 1,201 \quad 1}$
4. $\Delta Pr = \frac{4n}{s} \times \frac{V^2}{2g'}$	$= 2,7237$ psi
$= \frac{4 \quad 2}{0,0296} \times 0,0010$	$\Delta P_T < 10$ psi
$= 0,270$ psi	

$\Delta P_T = \Delta P_t + \Delta Pr$ $= 0{,}4365$ psi $\Delta P_T < 2$ psi	

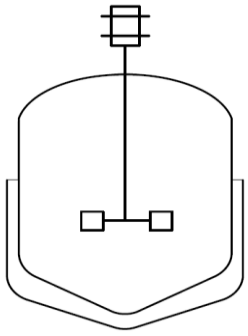
Rd perhitungan > Rd data (Kern ; T 12)

0,0033	>	0,0030	untuk media air		memenuhi
$\Delta P_T < 10$ psi	P shell	=	2,723708	psi	memenuhi
$\Delta P_T < 2$ psi	P tube	=	0,4365	psi	memenuhi

Spesifikasi :

Fungsi	:	Memanaskan $Al_2(SO_4)_3$ sampai suhu 90^oC
Type	:	Shell and tube, 1-2 exchanger (Fixed tube)
Dasar pemilihan	:	Umum digunakan dan mempunyai range perpindahan panas yang besar
Shell side	:	
ID	:	10,00 in
B	:	2,00 in
n	:	2 passes
Tube side	:	
Nt	:	40 buah
L	:	6 ft
OD	:	3/4 in
BWG	:	12
n	:	2 passes
Pitch	:	Square pitch 1"
Heat exch, area A	:	49,151 ft2
Jumlah heat exch	:	1
Bahan konstruksi	:	Carbon Steel

18. REAKTOR (R-210)



Nama alat : Reaktor Berpengaduk
Kode alat : R-210

Bahan kontruksi : carbon stell , Sa - 283 grade C
Proses operasi : semi continue dengan waktu tinggal 90 menit
Fungsi : Untuk mereaksikan $Al_2(SO_4)_3$ dengan $(NH_4)_2\ SO_4$ neghasilkan $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$
Type : Silinder tegak dengan tutup atas berbentuk dished atau tutup bawah berbentuk conical dilengkapi pengaduk dan jaket
Kondisi Operasi : Suhu reaksi = 90 ^oC
= 194 ^oF
= 363,15 ^oK
Tekanan = 1 atm
= 14,7 psi
(US Patent ,1957)

Dimensi ratio, H/D = H = 2 D
Komposisi bahan masuk

Komponen	Berat	Fraksi berat	ρ (gr/cm^3)
$Al_2(SO_4)_3$	5021,5033	0,2132	2,67
$(NH_4)_2SO_4$	2672,5691	0,1135	1,77
H2SO4	0,7229	0,00003	1,97
H_2O	15860,1183	0,6733	1
Total	23554,914	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}2132}{2{,}67} + \frac{0{,}1135}{1{,}77} + \frac{3{,}E\text{-}05}{1{,}97} + \frac{0{,}6733}{1}} \times 62{,}43$$

= 76,3869 lb/cuft

a. Penentuan Volume Tangki

Densitas campuran = 76,3869 lb/cuft
Rate Produk = 23554,914 kg/jam
= 51929,633 lb/jam

ρ campuran = ρ bahan

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

$$= \frac{51929{,}633 \text{ lb/jam}}{76{,}3869 \text{ lb/cuft}}$$
$$= 679{,}8240141 \text{ cuft/jam}$$

Direncanakan waktu oprasi sel 1,5 jam dengan 1 buah tangki, sehingga :

waktu tinggal = $\frac{\text{Volume Reaktor}}{\text{Rate volumetri}}$

Volume reaktor = 1,5 679,8240141

= 1019,74 cuft/jam

Asumsi bahan mengisi 80%
sehingga 20% ruang kosong

volume reaktor dengan ruang l = 1019,736021 + 203,947204

= 1223,683225 cuft/jam

Volume liquid mengisi 80% volume reaktor, sehingga volume larutan :

volume larutan = 1019,74 cuft

= 1019,7360 cuft

$H = 2\ D$

$V_s = (\pi/4) \times Ds^2 \times Hs$

$= (\pi/4) \times Ds^3 \times 2$

$= 1{,}5700\ Ds^3$

$V_{\text{tutup atas}} = 0{,}000049\ Ds^3$ (Brownell : 88)

$V_{\text{tutup bawah}} = (\pi\ Ds^3) / 24\ tg\alpha$ (Hesse, 1962)

$= \frac{3{,}14 \times Ds^3}{24 \times tg\ 30^o}$

$= 0{,}0204\ Ds^3$

$V_t = V_s + V_{\text{tutup atas}} + V_{\text{tutup bawah}}$

$1223{,}6832 = 1{,}5700\ Ds^3 + 0{,}000049\ Ds^3 + 0{,}0204\ Ds^3$

$1223{,}6832 = 1{,}5905\ Ds^3$

$D = 9{,}1632$ ft

≈ 9 ft $= 108$ in

$H = 18{,}3264$ ft

≈ 18 ft $= 216$ in

Pengecekan

$\frac{H}{D} = \frac{18{,}3264}{9{,}1632} = 2$ (memenuhi)

b. Tebal Shell

Tinggi liquid dalam shell :

Volume liquid	=	V_s				+	V_{alas}			
1019,7360	=	(π/4) x h x Ds^2				+	0,0204	Ds^3		
1019,7360	=	0,785	x	h	x	81	+	0,0204	x	729
h	=	15,8032	ft							
	=	4,8200	m							

c. Menentukan Tekanan Design

P_{oprasi} = 1 atm ⟶ 14,7 psi

$P_{hidrostatis}$ = ρ x (g / gc) x h

$$= \frac{76,3869 \times 1 \times 15,8032}{144}$$

= 8,3830 psi

P_{design} = (P_{oprasi} + $P_{hidrostatis}$) x 1,25

= (14,7 + 8,3830) x 1,25

= 28,8538 psi

Dipergunakan bahan konstruksi yang terbuat dari Carbon Steel dengan spesifikasi SA 201 grade A

$f_{allowable}$ = 13750 (Brownell : Tabel 13.1)

C = 0,125 in

Sambungan las dengan type double welded butt joint

Efisiensi las, E = 0,8

r = 1/2 x 9

= 4 1/2 ft 54 in

Rumus tebal shell yang digunakan adalah :

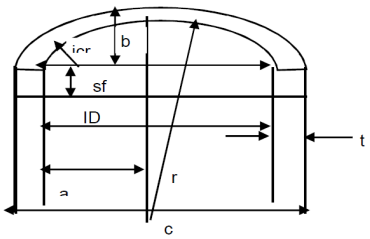
$$t_{min} = \frac{P \times ri}{fe - 0,6P} + C$$ (Brownell : Pers 13-1)

$$= \frac{(28,8538 \times 54)}{((13750 \times 0,8) - (0,6 \times 28,854))} + 1/8$$

= 0,2669 in

Diambil tebal shell = 1/3 in

Penentuan dimensi tutup atas, dished



Tutup atas berbentuk standart dished

OD = ID + 2ts
= 9,0 + 2 x 1/3
= 9 5/8 ft
= 115 1/2 in
rc = L = OD

Tinggi tutup (h) = $L - (L^2 - (D^2/4))^{0,5}$ (Hesse, 1962)
= 9 5/8 - (92 2/3 - 20 1/4)^{0,5}
= 1,1167 ft

Volume dishead = 1,1 x h^2 (3rc - h)
= 1,1 x 1,2471 x (3 x 9 5/8 - 1,1167)
= 38,0788 cuft

Bentuk : Flanged and standart dishead head

Tebal standart toripherical dished (atas)

$$t = \frac{0,885 \times P_d \times r_c}{(f \times E - 0,1P_d)} + C$$ (Brownell & Young, 1959)

Dimana :

P_d = Tekanan desain (psi)
r_c = Diameter luar (m)
E = Faktor Pengelasan 80%
t = Tebal dinding minimal (in)

$$t = \frac{0,885 \times 28,8538 \times 115\ 1/2}{(13750 \times 0,8)-(0,1 \times 28,854)} + 0,125$$

t = 0,3932 in

Diambil tebal head sebesar 4/9 in

Tutup bawah berbentuk conical

$$h = \frac{tg\alpha \times (D - m)}{2}$$ (Hesse, 1962)

Dimana :

D : Diameter bejana (ft)
tgα : Sudut Conis 30^o
m : 12" = 1 ft (Hesse, 1962)

$$h = \frac{tg\ 30^o \times (9 - 1)}{2}$$

h = 2,3094 ft

Volume conical = 0,262 h (D^2 + D m + m^2)
= 0,262 x 2,3094 x 91
= 55,0607 cuft

Bentuk : Standart conical dished

$$t = \frac{P_d \times r_c}{2 \cos 60 \, (f E - 0{,}6 P_d)} + C \qquad \text{(Brownell; 259)}$$

Dimana :

P_d = Tekanan desain (psi)
E = Faktor pengelasan 80%
t = Tebal dinding minimal (in)

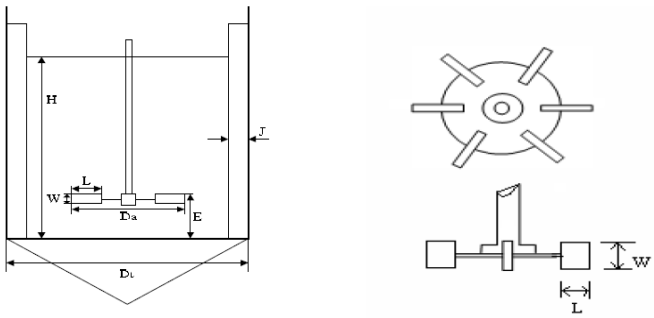
$$t = \frac{(\quad 28{,}8538 \quad \times \quad 115\ 1/2 \quad)}{2 \cos 30 \ ((\quad 13750 \quad 0{,}8) - (\quad 1 \quad \times \quad 28{,}854 \quad)} + 1/8$$

t = 1,1086 in
Diambil tebal head 1 in

Sistem Pengaduk
Dipilih pengaduk type flat blade turbine dengan jumlah blade 6

1. Penentuan Dimensi Pengaduk

Tinggi bahan total H_L = 15,8032 = 189,6383 in
Diameter dalam tangki D_t = 9,1632 = 109,9585 in



Ukuran pengaduk diambil dari (Mc. Cabe: 247) :

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

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

$\frac{W}{Da} = \frac{1}{5}$

Diameter impeler (Da) = 1/3 diameter shell = $\frac{1}{3}$ x 9,1632 = 3,0544 ft

Lebar blade (w) = 1/5 diameter impeller = $\frac{1}{5}$ x 3,0544 = 0,6109 ft

Panjang blade (L) = 1/4 diameter impeller = $\frac{1}{4}$ x 3,0544 = 0,7636 ft

Jarak impeler dari dasar (E) = 1/3 diameter shell = $\frac{1}{3}$ x 9 = 3,0544 ft

Lebar baffle (J) = 1/12 diameter shell = $\frac{1}{12}$ x 9 = 0,7636 ft

Tebal pengaduk = $\frac{1}{10}$ x 0,7636 = 0 ft = 0,9163 in

Keterangan :

Da = Diameter pengaduk
Dt = Dimeter tangki
L = Panjang blade
W = Lebar blade
E = Jarak pengaduk dari dasar tangki
J = Lebar baffle

2. Penentuan Jumlah Pengaduk

Tinggi bahan total H_L = 15,8032 ft

Diameter dalam tangki D_t = 9,1632 ft

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

$$= \frac{76,3869 \text{ lb/cuft}}{62,303 \text{ lb/cuft}} \times 0,996$$

$$= 1,2212$$

$$\text{Jumlah impeler} = \frac{\text{tinggi larutan}}{\text{diameter bejana}} \times sg$$

$$= \frac{15,8032}{9,1632} \times 1,2212$$

$$= 2,1060$$

Jadi jumlah impeler sebanyak = 2 buah

3. Penentuan Power Motor

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

$$= \frac{1,2212 \times 0,00085}{0,996}$$

= 0,0010 lb/ft dt (berdasarkan sg bahan)

ρ campuran = 76,3869 lb/cuft

Kecepatan putaran pengadukan jenis turbin antara 200-250 m.min)

Ditetapkan kecepatan pengaduk N = 100 rpm = 2 rps

Putaran pengaduk, V = π x N x Da (Joshi: 389)

= π x 100 x (3,0544 x 1/3)

= 319,6940 m/min (memenuhi)

Bilangan Reynolds (Nre)

$$Nre = \frac{\rho \times D^2 \times N}{\mu} = \frac{76{,}3869 \times 9{,}3294 \times 2}{0{,}0010}$$

= 1367641,745 (aliran trubulen)

Perhitungan power pengaduk yang dibutuhkan :

Diperoleh nilai Nre > 10000, sehingga Np = K_T

K_T = Np = 1,2 (Ludwig, Fig 5-13)

$$P = \frac{K_T N^3 Da^5 \rho}{gc}$$ (Mc Cabe : 257 Pers 9.12b)

$$P = \frac{1{,}2 \times 8 \times 265{,}8464 \times 76{,}3869}{32{,}17}$$

= 6059,959569 ft.lbf/s

= 6059,959569 / 550

= 11,0181 hp

(Joshi : 424)

Power Losses pada Gland 10% hp = 0,1 x 11,0181

= 1,1018 hp

Diambil power = 1 hp

Power input dengan gland losses = 11,0181 + 1,1018

= 12,1199 hp

Transmission sistem losses 20% = 0,2 x 12,1199

= 2,4240 hp

Power total = 12,1199 + 2,4240

= 14,5439 hp

Karena jumlah pengaduk 2 buah, maka power = 2 x 14,5439

= 29,0878 hp

Efesiensi motor = 85%

Sehingga power motor = $\frac{29{,}0878}{0{,}85}$

= 34,22094815 hp ≈ 34 hp

3. Perhitungan Sistem Pemanas

Sebagai media pemanas digunakan steam dengan 148 ^oC untuk menjaga suhu supaya suhu dalam reaktor 90 ^oC

Koefisien perpindahan panas bagian luar jaket :

$$hc = 0.87\ k/Di\ [("[" (L^2 \rho N)/\mu "]")]^{(2/3)}\ [(c\ \mu)/k]^{(1/3)}\ [\mu/\mu\omega]^{0.14}$$ (Kern, 722)

= 4344,5169 Btu/hr °F

Keterangan :

L = Da = Diameter impleller = 3,0544 ft
N = Putaran pengaduk = 100 rpm
ρ = Berat jenis = 76,387 lb/cuft
μ = Viscositas larutan = 0,0010 lb/ft s = 1,55088 cp
c = kapasitas panas campuran = 1,86 Btu/lb °F
k = Konduktifitas larutan = 0,0677 [1 - 0,0003 (t - 32] / sg (Perry,2008)
= 0,0527 Btu/hr ft² (°F/ft)

Koefisien perpindahan panas bagian dalam jaket (hi)

Dari ketn tabel 10, dipakai pipa 16 BWG dengan ukuran :

OD = 1,5 in
ID = 1,37 in
flow area = 1,47 in2
surface per 1 in ft (a) = 0,393 ft2

Data perhitungan :

Panas yang harus diserap (Q) = 19799273,53 kkal/jam
= 78523918,84 btu/jam
Rate pemanas = 39110,91221 kg/jam
= 86224,69929 lb/jam
Densitas steam = 0,152 lb/cuft
2,4348 kg/m3

$$V = \frac{W}{\rho \times A}$$

$$= \frac{39110,91221}{2,4348 \times 0,001}$$

= 16063256,58 m/jam
= 44620,15717 m/s
= 146398,7357 fps

Dari Kern hal 164 didapat harga hi = 1500 Btu/j ft^2 ^{o}F

hio = hi (ID/OD) = 1500 x (1,37 / 1,5)
= 1370 Btu/j ft^2 ^{o}F

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

$$= \frac{1500 \times 1370}{}$$

$$= \frac{1500 + 1370}{}$$

$= 716{,}0278746$ Btu/j ft^2 ^oF

Rd = 0,001 (Tabel 12) (Kern, 1988)

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

$$\frac{1}{Ud} = \frac{1}{716{,}0278746} + 0{,}001$$

Ud = 417,2588832

Fluida dingin (^oF)		Fluida panas (^oF)	diff
194,00	Higher Temp	298,00	104,00
176,00	Lower Temp	298,00	122,00
18,00	diff	0	18,00

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

$$= \frac{104{,}00 - 122{,}00}{\ln \frac{104{,}00}{122{,}00}}$$

$= 112{,}8$ ˚F

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

$$= \frac{78523918{,}8359}{417{,}259 \times 112{,}76}$$

$= 1668{,}9325$ ft^2

Menentukan tinggi jaket

Tinggi jaket = tinggi shell + tinggi tutup bawah

h = 18,3264 + 2,3094

h = 20,6358

Asumsi :

Tebal steam (s) = 8 in

Tebal jaket (tj) = 0,1875 in

Effisiensi sambungan las, E = 0,8

Faktor korosi (c) = 1/8

Dipergunakan bahan kontruksi yang terbuat dari carbon steel dengan :
spesifikasi, SA-283 grade C

Do (bejana) = Di + 2ts
= 9 4/5 in
Di (jaket) = Dob + 2s
= 25,78820525 in
Do (jaket) = Di j + 2tj
= 26,1632 in
P desain jaket = (Po-Pi) jaket x 14,7 psia
= 51,45 psia

Penentuan Tebal jaket :
Tebal jaket berdasarkan ASME Code untuk cylindrical tank:
t = (P x Dij) / (2 fe - P) + C

Dimana :
Pd = Tekanan desain (psi)
Dij = Diameter dalam jaket (in)
E = Faktor pengelasan 0,8
t = Tebal dinding minimal (m)

$$0{,}1875 = \frac{51{,}45 \times 25{,}7882}{(f\ 1{,}6 - 51{,}45)} + 1/8$$

$$0{,}0625 = \frac{1326{,}80316}{(f\ 1{,}6 - 51{,}45)}$$

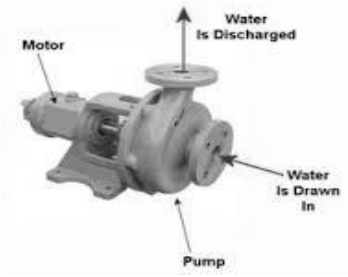
0,1 f - 3 = 1326,80316
f = 13300,18785 (f desain)

f all > f desain
13750 > 13300 (memenuhi)
Diambil tebal jaket 0,1875

Spesifikasi :
Fungsi = Untuk mereaksikan $Al_2(SO_4)_3$ dengan $(NH_4)_2\ SO_4$ menghasilkan $Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$
Type = Silinder tegak dengan tutup atas berbentuk dishead dan tutup bawah berbentuk conical dilengkapi pengaduk dan jaket
Bahan kontruksi = Carbon steel, SA-283 grade C
Kondisi oprasi
Suhu reaksi = 90 ^oC
Tekanan = 1 atm
Waktu tinggal = 90 Menit
Proses oprasi = continue

Jumlah	=	1 buah	
Dimensi Reaktor :			
Tinggi bejana	=	18	ft
Diameter bejana	=	9,0	ft
Tebal bejana	=	1/3	in
Dimensi Tutup :			
Tebal tutup atas	=	4/9	in
Tebal tutup bawah	=	1	in
Pengaduk :			
Jenis pengaduk	=	Tipe flate blade turbin dengan jumlah blade 6 buah	
Jumlah impeller	=	2 buah	
Diameter impeller	=	3,0544	ft
Lebar blade	=	0,6109	ft
Jarak impeller	=	3,0544	ft
Lebar baffle	=	0,7636	ft
Type poros	=	Conmmercial hot rolled steel	
Putaran	=	100	rpm
Daya motor	=	34	hp
Tebal jaket	=	0,1875	in
Tinggi jaket	=	20,6358	ft

19. POMPA -4 (L-211)



Fungsi = Memindahkan bahan dari reaktor ke Tangki Penyimpanan
Type = Centrifugal Pump
Dasar pemilihan = Sesuai untuk viskositas <10 cP dan bahan liquid
Bahan Masuk

Komponen	Berat	raksi ber	ρ (gr/cm^3)
$Al_2(SO_4)_3(NH_4)_2SO_4.24H_2O$	12637,4499	0,4272	1,65
$Al_2(SO_4)_3$	251,0752	0,0085	2,67
$(NH_4)_2SO_4$	831,3512	0,0281	1,77
H_2SO_4	0,7229	2,E-05	1,97
H_2O	15860,1183	0,5362	1
Total	29580,717	1,0000	

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ komponen}}} \times 62$$

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0,4272}{1,65} + \frac{0,0085}{1,6500} + \frac{0,0281}{1,77} + \frac{2,E\text{-}05}{1,97} + \frac{0,54}{1}} \times 62,43$$

$$= 76,4961 \text{ lb/cuft}$$

Data perhitungan :

Rate bahan	=	29580,717	kg/jam
	=	65214,241	lb/jam
ρ campuran	=	76,4961	lb/cuft
	=	1,2255	gr/ml

$$\text{Rate volumetrik} = \frac{\text{rate massa}}{\rho \text{ campuran}} = \frac{65214,241 \text{ lb/jam}}{76,4961 \text{ lb/cuft}}$$

= 852,516719 cuft/jam
= 14,2086 cuft/menit
= 106,2878 gpm

Perhitungan diameter pipa

Asumsi aliran Turbulen :

Diameter optimum untuk turbulen, Nre >4000 digunakan persamaan :

$Di \text{ optimum} = 3.9 \times qr^{0,45} \times \rho^{0,13}$ (Peters, ed.4 pers.15 hal 496)

Dengan : qr = Fluid flow rate , ρ = fluid density ; lb cuft

qr = 14,2086 cuft/menit
= 0,23681 cuft/s

Diameter pipa optimum = $3.9 \times qr^{\circ,45} \times \rho^{\circ 13}$ (Peters, ed.4 pers.15 hal 496)
= 3,5844 in

Dipilih pipa 3 1/2 in, sch 80 (Brownell & Young,1987)

OD	=	4	in	0,33333 ft
ID	=	3,364	in	0,28033 ft

Luas , A = $(1/4.\ \pi.\ ID^2)$
= 0,0617 ft^2

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

$$= \frac{76,4961 \text{ lb/cuft}}{62,303 \text{ lb/cuft}} \times 1$$

= 1,2229

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

$$= \frac{1{,}2229 \times 0{,}001}{0{,}996}$$

= 0,0012 lb/ft s (berdasarkan sg bahan)

= 1,8272 cp

Kecepatan aliran (V) = $\frac{\text{Rate volumetrik}}{\text{Luas, A}}$ $\frac{\text{cuft/dt}}{\text{ft}^2}$ g = 416061545

= 3,8387 ft/dt

$$\text{Nre} = \frac{D\,V\,\rho}{\mu} = \frac{0{,}28033 \times 3{,}8387 \times 76{,}4961}{0{,}0012}$$

= 67044,7793 > 4000 (asumsi turbulen benar)

Menentukan jumlah energi yang hilang

1. Karena pipa lurus

Ditetapkan :

Panjang pipa lurus = 30 ft

Dipilih pipa Galvanized iron = 0,00015 (Geankoplis : 88)

maka harga e/D = 0,001

f = 0,007 (Geankoplis : 88)

gc = 32,174 ft.lbm/dt².lbf

2. Karena friksi (Geankoplis : 88)

Taksiran panjang pipa lurus					=	30	ft
4 elbow 90°	=	4	x	35 x ID pipa	=	39,2467	ft
1 gate valve	=	1	x	7 x ID pipa	=	1,96233	ft
Panjang total pipa					=	71,209	ft

Friksi yang terjadi :

1. Friksi karena gesekan bahan dalam pipa :

$$F1 = (2f \times V^2 \times Le)/(gc \times D) = 1{,}62872 \ \frac{\text{ft. lbf}}{\text{lbm}}$$

2. Friksi karena kontraksi dari tangki ke pipa:

(α= 1 untuk aliran turbulen)

$F2 = (K \times V2^2)/(2 \times \alpha \times gc)$ = 0,01145 ft. lbf / lbm (K= 0,1 A tangki >>>Apipa)

(Peters ed.4 hal 484)

3. Friksi karena ekspansi dari pipa ke tangki:

$$F_3 = \frac{V^2}{2 \times \alpha \times gc} = \frac{{}_2^2 - \Delta V_1^2}{2 \times \alpha \times gc} = 0{,}229 \ \frac{\text{ft. lbf}}{\text{lbm}}$$

(V_1 <<<< V_2, maka V_1 dianggap = 0)

4. Friksi karena Elbow 90^o

$$F_4 = \frac{K_f \times V_1^2}{2}$$

$$= \frac{0{,}75 \times 14{,}735}{}$$

$$= \frac{}{2}$$

$$= 5{,}5258$$

5. Friksi karena Gate Valve

$$F_5 = \frac{K_f \times V_1^2}{2}$$

$$= \frac{0{,}17 \times 14{,}735}{2}$$

$$= 1{,}2525$$

ΣF(Total Friksi)

$$= F_1 + F_2 + F_3 + F_4 + F_5$$

$$= 1{,}6287 + 0{,}0114 + 0{,}2290 + 5{,}526 + 1{,}2525$$

$$= 8{,}6475 \ \frac{ft.lb_f}{lb_m}$$

Persamaan Bernoulli :

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

$P_1 = P_{hidrostatis}$

Diketahui data

Tinggi bahan = 15,8032 ft (Reaktor)

ρ bahan = 76,4961 lb/cuft

$P_{hidrostatis} = \rho \cdot g/gc \cdot H$

$= 76{,}4961 \times 15{,}8032$

$= 1208{,}882916 \ lb/ft^2$

$P_2 = 1 \ atm = 15 \ psi$

$= 15 \times 144$

$= 2116{,}8000 \ lbf/ft^2$

$\Delta P = P_2 - P_1$

$= 2116{,}80 - 1208{,}9$

$= 907{,}9171 \ lb_f/ft^2$

$$\frac{\Delta P}{\rho} = \frac{907{,}9171 \ lb_f/ft^2}{76{,}4961 \ lb_m/ft^3}$$

$$= 11{,}8688 \ \frac{ft.lb_f}{lb_m}$$

Energi Potensial

$Z_2 = 36$ ft Tangki Penyimpanan

$Z_1 = 15{,}803$ ft

Asumsi : g/gc = 1

g percepatan gravitasi = 32 ft/dt^2

gc konstanta gravitasi = 32 ft/dt^2 x lb_m/lb_f

$$\Delta Z \frac{g}{gc} = 20{,}197 \text{ ft} \times \frac{32 \text{ ft/dt}^2}{32 \text{ ft.lb}_m/\text{dt}^2.\text{lb}_f}$$

$$= 20{,}197 \frac{\text{ft . Lbf}}{\text{lbm}}$$

Energi Kinetik

$$\frac{\Delta V^2}{2 \times gc \times \alpha} = \frac{14{,}7354}{2 \times 32 \times 1}$$

$$= 0{,}2288 \frac{\text{ft.lb}_f}{\text{lb}_m}$$

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

$$= 11{,}87 + 20{,}197 + 0{,}2288 + 8{,}647$$

$$= 40{,}9419 \frac{\text{ft.lb}_f}{\text{lb}_m}$$

$$hp = \frac{Wf \times qr \times \rho}{550}$$

$$= \frac{40{,}94 \times 0{,}2368 \times 76{,}4961}{550}$$

$$= 1{,}3485 \text{ hp}$$

Effisiensi pompa = 31% (Peters & Timmerhaus : fig 14-36)

$$Bhp = \frac{hp}{\eta \text{ motor}} = \frac{1{,}3485}{0{,}31} = 4{,}34994021 \text{ hp}$$

Effisiensi motor = 82% (Peters&Timmerhaus : fig 14-38)

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

$$= \frac{4{,}35}{82\%}$$

$$= 5{,}3048 \text{ hp}$$

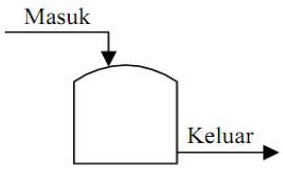
digunakan power = 5,30 hp

Spesifikasi :

Fungsi	=	Memindahkan bahan dari reaktor ke Tangki Penyimpana
Jenis	=	Pompa centrifugal
Kapasitas	=	29580,717 kg/j
Power	=	5 hp
eff. Pompa	=	31%
eff. Motor	=	82%
Jumlah	=	1 pompa

Bahan kontruksi = Carbon Stell

20. TANGKI PENAMPUNG (F-220)



Bahan baku masuk:

Komponen	Masuk (Kg/jam)	Fraksi berat	ρ (gr/cc) [Perry 7ed;T.2-1]
l2(SO4)3(NH4)2SO4.24H2	12637,4499	0,4272	1,6500
Al2(SO4)3	251,0752	0,0085	2,6700
(NH4)2SO4	831,3512	0,0281	1,7700
H2SO4	0,7229	0,000024	1,9700
H2O	15860,1183	0,5362	1,0000
TOTAL	29580,7175	1,0000	

Perhitungan :

ρ campura = $1/(\sum(\text{fraksi berat})/(\rho \text{ komponen}))$ x 62,43

(1 gr/cc = 62,43 lb/cuft)

ρ bah = $1/(0{,}4272/1{,}65 + 0{,}0085/2{,}67 + 0.0281/1.77 + 0{,}0000024/1{,}97 + 0{,}5362/1{,}000)$ x 62,43

= 76,681 lb/cuft

ρ bahan = ρ campuran

= 76,6808 lb/cuft

Rate massa = 29580,7175 kg/jam

= 65213,6498 lb/jam

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

= $\frac{65213{,}650 \text{ lb/jam}}{76{,}6808 \text{ lb/cuft}}$

= 850,4562 cuft/jam

Direncanakan penyimpanan tangki dengan 2 buah tangki,
sehingga volume masing-masing tangki :

Volume tangki = $\frac{850{,}4562 \times 1 \times 24}{2}$

= 10205,4743 cuft

Untuk 1 tangki di upsize untuk 3 kali penampungan slurry maka

= 10205,4743 x 3

= 30616,4229 cuft

Asumsi bahan mengisi 80% volume tangki, maka :

Volume tangki = $\frac{30616,423}{80\%}$

= 38270,529 cuft

Perhitungan Ukuran Tangki dan Ketebalannya :

Asumsi dimenti = 1

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

38270,53 cuft = $\frac{3,14 \times D^2 \times D}{4}$

153082,1 cuft = $3,14 \times D^3$

48752,27 cuft = D^3

36,5 ft = D

438,4 in =

36,5 ft = H

438,4 in =

Perhitungan Tebal Minimum Shell :

Tebal shell berdasarkan ASME Code untuk cylindrical tank adalah

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

(Brownell and Young; Pers. 13-1, 254)

dimana :

t mir = Tebal shell minimum; in

P = Tekanan tangki; lb/in^2

ri = Jari-jari tangki; in

C = Faktor korosi; in (C = 1/8)

E = Faktor pengelasan, digunakan double welded,
E = 0,8 (Brownell and Young; 254)

f = Stress allowable, bahan konstruksi Stainless
Steel tipe 31600 lb/in^2
(Perry 7^{ed}; T.28-11)

P operasi = P hidrostatis

$$= \frac{\rho \times H}{144}$$

$$= \frac{76{,}6808 \times 36{,}5313}{144}$$

$$= 19{,}4531 \text{ lb/in}^2$$

P design diambil 10% lebih besar dari P hidrostatis untuk faktor keamanam

$$P_{design} = 1{,}1 \times (P_{op} + P_{hidrostatik})$$

$$= 1{,}1 \times 19{,}4531$$

$$= 21{,}3984 \text{ lb/in}^2$$

$$ri = \frac{D}{2} = \frac{438{,}3754}{2} = 219{,}1877 \text{ in}$$

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

$$= \frac{21{,}3984 \times 219{,}1877}{31600 \times 0{,}8 - 0{,}6 \times 21{,}3984} + 1/8$$

$$= 0{,}3156 \text{ in digunakan } 1/2 \text{ in}$$

Untuk tebal tutup atas karena tekanan atmosphoric, maka tebal tutup atas disamakan dengan tebal shell, t_s = 1/2 in

Untuk tebal tutup bawah datar karena tutup menumpang diatas semen, maka teba = 1/4 i (Brownell and Young; 58)

Perhitungan Tinggi (Brownell and Young; 87)

t = t_s

= 1/2 in

= 2 in

sf = 2 in (Brownell and Young;T 5.4; 87)

icr = 1,5 in (Brownell and Young;T 5.4; 87)

icr = irr

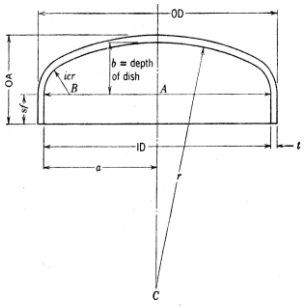
= 1,5 in

= 1,5 in

ID = D tangki

= 36,5 ft

= 438,4 in



$$AB = \frac{ID}{2} - icr$$

$$= \frac{438{,}4}{2} - 1{,}5000 = 217{,}6877 \text{ in}$$

Untuk standart head, r = OD

OD = ID
= 438,4 in

BC = OD - icr
= 438,4 - 1,5000
= 436,8754 in

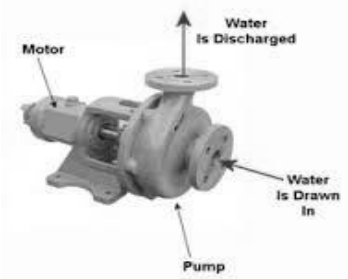
b = OD - $\sqrt{(BC^2 - AB^2)}$
= 438,3754 - $\sqrt{}$ (190860,12 - 47387,9360)
= 438,3754 - 378,7772
= 59,5982 in

OA = t + b + sf
= 2 + 59,5982 + 2
= 63,6 in
= 5,3 ft

Spesifikasi :

Fungsi	=	Untuk menampung Hasil Reaktor Yang Akan Menuju Evaporator
Tipe	=	Silinder tegak, tutup bawah datar, tutup atas dished
Dasar pemiliha	=	Sesuai untuk penyimpanan larutan Basa
Volume	=	30616,423 cuft
Diameter	=	36,5 ft
Tinggi silinder	=	36,5 ft
Tinggi tutup ata	=	5,3 ft
Tebal shell	=	1/2 in
Tebal tutup atas	=	1/2 in
Tebal tutup bawa	=	1/4 in
Bahan konstruk	=	Stainless Steel tipe AISI-316
Jumlah	=	2 buah

21. POMPA -5 (L-221)



Fungsi	=	Memindahkan bahan dari tangki penyimpan ke heater evaporator
Type	=	Centrifugal Pump

Dasar pemilihan = Sesuai untuk viskositas <10 cP dan bahan liquid

Bahan Masuk

Komponen	Berat	Fraksi berat	ρ (gr/cm^3)
$Al_2(SO_4)_3(NH_4)_2SO_4.24H_2O$	12637,4499	0,4272	1,65
$Al_2(SO_4)_3$	251,0752	0,0085	2,67
$(NH_4)_2SO_4$	831,3512	0,0281	1,77
H_2SO_4	0,7229	2,E-05	1,97
H_2O	15860,1183	0,5362	1
Total	29580,717	1,0000	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}4272}{1{,}65} + \frac{0{,}0085}{2{,}6700} + \frac{0{,}0281}{1{,}77} + \frac{2\text{E-}05}{1{,}97} + \frac{0{,}5362}{1}} \times 62{,}43$$

= 76,6808 lb/cuft

Data perhitungan :

Rate bahan = 29580,717 kg/jam
= 65214,241 lb/jam

ρ campuran = 76,6808 lb/cuft
= 1,2284 gr/ml

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

$$= \frac{65214{,}241 \text{ lb/jam}}{76{,}6808 \text{ lb/cuft}}$$

= 850,4639073 cuft/jam
= 14,1744 cuft/menit
= 106,0319 gpm

Perhitungan diameter pipa

Asumsi aliran Turbulen :

Diameter optimum untuk turbulen, Nre >4000 digunakan persamaan :

Di optimum = $3.9 \times qr^{0,45} \times \rho^{0,13}$ (Peters, ed.4 pers.15 hal 496)

Dengan : qr = Fluid flow rate , ρ = fluid density ; lb cuft

qr = 14,1744 cuft/menit

= 0,23624 cuft/s

Diameter pipa optimum = $3.9 \times qr^{0,45} \times \rho^{0,13}$ (Peters, ed.4 pers.15 hal 496)

= 3,5816 in

Dipilih pipa 3 1/2 in, sch 80

OD = 4 in 0,33333 ft

ID = 3,364 in 0,28033 ft

Luas , A = $(1/4.\ \pi.\ ID^2)$

= 0,0617 ft^2

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

$$= \frac{76,6808 \text{ lb/cuft}}{62,303 \text{ lb/cuft}} \times 0,996$$

= 1,2258

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

$$= \frac{1,2258 \times 0,001}{0,996}$$

= 0,0012 lb/ft s (berdasarkan sg bahan)

= 1,8316 cp

Kecepatan aliran (V) = $\frac{\text{Rate volumetrik cuft/dt}}{\text{Luas, A } ft^2}$ g = 416061545

= 3,8294 ft/dt

$$Nre = \frac{D\ V\ \rho}{\mu} = \frac{0,28033 \times 3,8294 \times 76,6808}{0,0012}$$

= 66883,3393 > 4000 (asumsi turbulen benar)

Menentukan jumlah energi yang hilang

1. Karena pipa lurus

Ditetapkan :

Panjang pipa lurus		=	30	ft
Dipilih pipa Galvanized iron		=	0,00015	(Geankoplis : 88)
maka harga	e/D	=	0,001	
	f	=	0,007	(Geankoplis : 88)
	gc	=	32,174	ft.lbm/dt².lbf

2. Karena friksi (Geankoplis : 88)

Taksiran panjang pipa lurus							=	30	ft
4 elbow 90°	=	4	x	35	x	ID pipa	=	39,2467	ft
1 gate valve	=	1	x	7	x	ID pipa	=	1,96233	ft
Panjang total pipa							=	71,209	ft

Friksi yang terjadi :

1. Friksi karena gesekan bahan dalam pipa :

$$F1 = (2f \times V^2 \times Le)/(gc \times D) = 1{,}62088 \ \frac{\text{ft. lbf}}{\text{lbm}}$$

2. Friksi karena kontraksi dari tangki ke pipa:

$$F2 = (K \times V2^2)/(2 \times \alpha \times gc) = 0{,}01139 \ \frac{\text{ft. lbf}}{\text{lbm}}$$

(α= 1 untuk aliran turbul
(K= 0,05 A tangki >>>Apip
(Peters ed.4 hal 484)

3. Friksi karena ekspansi dari pipa ke tangki:

$$F_3 = \frac{V^2}{2 \times \alpha \times gc} = \frac{\Delta V_2^{\,2} - \Delta V_1^{\,2}}{2 \times \alpha \times gc} = 0{,}22789 \ \frac{\text{ft. lbf}}{\text{lbm}}$$

(V_1 <<<< V_2, maka V_1 dianggap = 0)

4. Friksi karena Elbow 90^o

$$F_4 = \frac{K_f \times V_1^{\,2}}{2} = \frac{0{,}75 \times 14{,}665}{2} = 5{,}4992$$

5. Friksi karena Gate Valve

$$F_5 = \frac{K_f \times V_1^{\,2}}{2} = \frac{0{,}17 \times 14{,}665}{2} = 1{,}2465$$

ΣF(Total Friksi)

$$= F_1 + F_2 + F_3 + F_4 + F_5$$
$$= 1{,}6209 + 0{,}0114 + 0{,}2279 + 5{,}499 + 1{,}2465$$
$$= 8{,}6059 \ \frac{\text{ft.lb}_f}{\text{lb}_m}$$

Persamaan Bernoulli :

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

P_1 = $P_{hidrostatis}$

Diketahui data

Tinggi bahan = 41,2705 ft (Evaporator)

ρ bahan = 76,6808 lb/cuft

$P_{hidrostatis}$ = ρ . g/gc .H

= 76,6808 x 41,2705

= 3164,654403 lb/ft^2

P_2 = 1 atm = 14,7 psi

= 14,7 x 144

= 2116,8000 lbf/ft^2

ΔP = $P_2 - P_1$

= 2116,80 - 3164,7

= 1047,8544 lb_f/ft^2

$$\frac{\Delta P}{\rho} = \frac{1047,8544 \ lb_f/ft^2}{76,6808 \ lb_m/ft^3}$$

$$= 13,6651 \ \frac{ft.lb_f}{lb_m}$$

Energi Potensial

Z_2 = 41 ft Evaporator

Z_1 = 30,000 ft

Asumsi : g/gc = 1

g percepatan gravitasi = 32 ft/dt^2

gc konstanta gravitasi = 32 ft/dt^2 x lb_m/lb_f

$$\Delta Z \frac{g}{gc} = 11,000 \ ft \times \frac{32 \ ft/dt^2}{32 \ ft.lb_m/dt^2.lb_f}$$

$$= 11,000 \ \frac{ft \ . \ Lbf}{lbm}$$

Energi Kinetik

$$\frac{\Delta V^2}{2 \times gc \times \alpha} = \frac{14,6645}{2 \times 32,2 \times 1}$$

$$= 0,2277 \ \frac{ft.lb_f}{lb_m}$$

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

$$= 13,67 + 11,000 + 0,2277 + 8,606$$

$$= \quad 33{,}4987 \quad \frac{ft.lb_f}{lb_m}$$

$$hp = \frac{Wf \times qr \times \rho}{550}$$

$$= \frac{33{,}50 \times 0{,}2362 \times 76{,}6808}{550}$$

$$= \quad 1{,}1033 \quad hp$$

Effisiensi pompa = 31% (Peters & Timmerhaus : fig 14-36)

$$Bhp = \frac{hp}{\eta \text{ motor}} = \frac{1{,}1033}{0{,}31} = 3{,}55912945 \quad hp$$

Effisiensi motor = 82% (Peters&Timmerhaus : fig 14-38)

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

$$= \frac{3{,}56}{82\%}$$

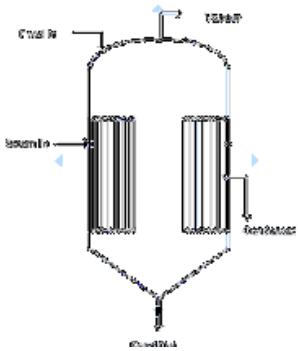
$$= \quad 4{,}3404 \quad hp$$

digunakan power = 4,3 hp

Spesifikasi :

Fungsi = Memindahkan bahan dari tangki penyimpan ke heater evaporator
Jenis = Pompa centrifugal
Kapasitas = 29580,717 kg/j
Power = 4 hp
eff. Pompa = 31%
eff. Motor = 82%
Jumlah = 1 pompa
Bahan kontruksi = Carbon Stell

22. EVAPORATOR (V-320)



Fungsi : Memekatkan larutan alumunium amonia sulfat
Type : Standart Vertical Tube Evaporator
Dasar pemilihan : Sesuai untuk proses pemekatan larutan

Perhitungan :
Data dari Appendix B
Q = 6681465,916 kkal/jam
26498693,82 Btu/jam

Suhu Masuk = 90 ^oC = 194 ^oF

Suhu Keluar = 100 ^oC = 212 ^oF

ΔT = 18 ^oF

UD = 700 diambil 200-700 Btu (Kern : 480)

Digunakan 1 buah evaporator, sehingga luas perpindhan panas evaporator :

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

$$= \frac{26498693,82}{700 \times 18}$$

$$= 2103,070938 \ ft^2$$

$$= 195,3815994 \ m^3$$

Luas perpindahan panas maksimum 300 m^2 (Ulrich : T.4-7)

Kondisi tube calandria berdasarkan Badger, 1955 :

Ukuran Tube = 4 in

Panjang Tube = 6 ft

Dipilih :

Pipa standart ukuran 4 in IPS schedule 40 (Kern : Tabel 11)

OD = 4,5 in

ID = 4,026 in = 0,3355 ft

a't = 12,7 in^2 = 0,08814 ft^2

$$\text{Jumlah tube (Nt)} = \frac{A'}{a't \cdot L}$$

$$= \frac{2103,070938}{0,53}$$

$$= 3977 \text{ buah}$$

Dimensi Evaporator :

Luas penampang (A) = Nt x a't

= 3977 x 0,0881

= 351 ft^2

$D_{evaporator}$ = √ 4 X A/π
= 21,1308 ft
= 6,4407 m

Tinggi evaporator berdasarkan diameter ratio

Asumsi dimensi ratio, H/D = 2

H = 2 x D
= 2 x 21,1308
= 42,2617 ft 12,8814 m

Diameter centrwall (Dew) = 6 - 24 ft (Vilbrandt hal 126)

Asumsi Dew = 1,0 x $D_{evaporator}$
= 21,1308 ft (Memenuhi range)

Menentukan tebal minimum shell

Tebal shell berdasarkan ASME code untuk cylinderical tank :

$$t_{min} = \frac{P \times ri}{fe - 0{,}6P} + C$$ (Brownell : pers 13-1)

Dengan :

t_{min} = Tebal shell minimum (in)
P = Tekanan tangki (psi)
ri = Jari - jari tangki
C = Faktor korosi ; 0,125
E = Faktor pengelasan, E = 0,8

Bahan kontruksi shell : Dianjurkan campuran alloy carbi steel dengan nickel
Dari B&Y didapatkan bahan kontruksi alloy Steel SA-203 Grade C (2 1/2 Ni)
fallowable = 18750 psi (B&Y : T13-1)
Poprasi = 1 atm = 14,7 psi
Pdesign diambil 10% dari besar dari Poprasi untuk faktor keamanan
Pdesign = 1,1 x 14,7
= 16,17 psi
r = 1/2 D
= 1/2 21,1308
= 10,5654 ft
= 126,7849658 in

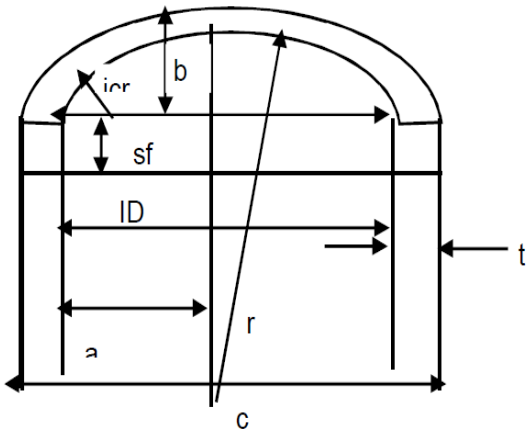
Rumus tebal shell yang digunakan adalah :

$$t_{min} = \frac{P \times ri}{fe - 0{,}6P} + C$$ (Brownell : 13-1)

$$= \frac{16{,}17 \times 126\ 7/9}{((18750 \times 0{,}8) - (0{,}6 \times 16{,}170))} + 1/8$$

= 0,26 in
Diambil tebal shell = 1/4 in

Penentuan dimensi tutup atas, dished



Tutup atas berbentuk standart dished

OD = ID + 2ts
= 21,131 + 2 x 1/4
= 21 5/8 ft
= 259,57 in

rc = 112 3/5 in 9 3/8 ft
rc = L

Tinggi tutup (h) = $L - (L^2 - (D^2/4))^{0,5}$ (Hesse, 1962)
= $9,382 - (88,027 - 111,63)^{0,5}$
= 9,382 - -3,1467
= 12,529 ft

Volume dishead = 1,1 x h^2 (3rc - h)
= 1,1 x 156,975 x (3 x 112 3/5 - 12,5290
= 56158,8110 cuft

Bentuk : Flanged and standart dishead head

Tebal standart toripherical dished (atas)

$$t = \frac{0,885 \times P_d \times r_c}{(f \times E - 0,1P_d)} + C$$ (Brownell : pers 13-12)

Dimana :

P_d = Tekanan desain (psi)
r_c = Diameter luar (m)
E = Faktor Pengelasan 80%

t = Tebal dinding minimal (in)

$$t = \frac{0{,}885 \times 16{,}170 \times 112\ 3/5}{(18750 \times 0{,}8) - (0{,}1 \times 16{,}170)} + 1/8$$

t = 0,2324 in

Diambil tebal head sebes 0,250 in

Tutup conical dished (bawah)

$$tc = \frac{PD}{2 \cos \alpha\ (fE - 0{,}6P)} + C$$

dengan, α = 1/2 sudit conis 60/2 = 30

$$tc = \frac{PD}{2 \cos \alpha\ (fE - 0{,}6P)} + C$$

$$= \frac{16{,}170 \times 259{,}57}{2 \cos 30 \times 14990{,}298} + 1/8$$

= 1,0326 in

maka digunakan = 1 in

Spesifikasi

Bagian Shell

Diameter Evaporator	=	21,131	ft
Diameter Centerwall	=	21,131	ft
Tinggi shell	=	42,262	ft
Tebal shell	=	1/4	in
Tebal tutup bawah	=	1	in
Tebal tutup atas	=	1/4	in

Tube Calandria

Ukuran	=	1/2	in sch 40 standard IPS
OD	=	4,5	in
ID	=	4,026	in
panjang tube	=	6	ft
jumlah tube	=	3977	buah
bahan kontruksi	=	carbon stell SA - 203 Grade C (2 1/2 in)	
jumlah evaporator	=	1	buah

23. CONDENSOR (E-321)

Fungsi : Mengubah fase $H_2O_{(g)}$ yan menguap dari evaporator menjadi $H_2O_{(l)}$

Data dari neraca panas

Q_{serap} = 5797638,491 kkal/jam

= 22993434,26 Btu/jam

T bahan masuk (T1) = 100 ^oC = 212 ^oF
T bahan keluar (T2) = 100 ^oC = 212 ^oF
T C.W masuk (t1) = 30 ^oC = 86 ^oF
T C.W keluar (t2) = 45 ^oC = 113 ^oF

Δt_1 = 212 - 113 = 99 $^\circ F$
Δt_2 = 212 - 86 = 126 $^\circ F$

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

$$= \frac{126 - 99}{\ln \frac{126}{99}}$$

= 112,0 $^\circ F$
= 317,57 ^oK

Untuk 1-2 shell & tube, FT = 0,75 sampai 0,8 (Kern : 225)
F_T = 0,8
$\Delta T = F_T$ x LMTD
= 0,80 x 111,9579
= 89,5663 $^\circ F$

Menghitung Tc dan tc
Tc = Tav steam

$$Tc = \frac{T_1 + T_2}{2} = \frac{212,00 + 212,00}{2}$$

= 212,00 ^oF

tc = tcav bahan

$$tc = \frac{t_1 + t_2}{2} = \frac{86,00 + 113,00}{2}$$

= 99,50 ^oF

Bahan masuk :

Komposisi	Berat	Fraksi Berat	ρ (gr/ml)
H_2O	6603,535807	1	1
Total	6603,535807	1	

Perhitungan :

ρ campuran = 1 gr/ml
= 62,422 lb/cuft

$$\text{sg bahan} = \frac{\rho \text{ bahan}}{\rho \text{ reference}}$$
$$= \frac{62,42197253}{62,42197253}$$
$$= 1$$

μ berdasarjan sg bahan : (Kern, 1988)

sg reference 1
μ reference 0,95 cp

$$\mu \text{ bahan} = \frac{\text{sg bahan}}{\text{sg reference}} \times \mu \text{ reference}$$
$$= \frac{1}{1} \times 0,95$$
$$= 0,95 \text{ cp}$$
$$= 0,0006 \text{ lb/ft s}$$

Condensor termasuk sistem cooler karena :

Hot Fluid : Gas
Cold Fluid : Water

Sehingga didapat nilai UD dengan mengambil nilai :

UD = 2 - 50 Btu/jam ft^2 ^oF (Kern : Tabel 8)

dipilih UD = 50 Btu/jam ft^2 ^oF

Digunakan 1 buah condensor, sehingga dapar dihitung :

$$A = \frac{Q}{UD \times \Delta T}$$
$$= \frac{22993434,2565}{50 \times 89,57}$$
$$= 5134,3925 \text{ } ft^2$$
$$= 477,0005 \text{ } m^2$$

Dari (Kern, Tabel 10), didapat data :

Pipa (Tube)

OD = 1 1/2 in
BW = 18
ID = 1,4 in

Flow area per tube (a') 1,54 in^2
Surface per lin ft (a") 0,3925 ft^2

disusun segitiga (Karena bahan encer μ bahan < 1 cp)
pitch 2 in

Asumsi :
panjang tube L = 16,0 ft

Jumlah Tube Nt $= \frac{A}{a'' \times L}$

$= \frac{5134,392}{0,3925 \times 16,0}$

= 817,5784 buah

$UD = \frac{Q}{A \quad T}$

$= \frac{22993434,2565}{5134,3925 \quad 89,5663}$

= 50

Harga Nt distandardkan sesuai ketetapan di tabel 9 (Kern, 1988)
pg. 841 (pitch persegi) dan pg. 842 (pitch segitiga)
Nt = 307 buah
maka diperoleh harga IDs 307 buah
Tube passes = 1
didapatkan :
ID Shell = 39 in (tabel 9, Kern)

Kemudian UD dikoreksi dengan menggunakan persamaan :

UD koreksi $= \frac{Q}{A \times \Delta T}$

$= \frac{22993434,2565}{5134,39 \times 89,5663}$

= 50,0000 Btu/jam $ft^2\,^oF$

Perencangan :
Type H 1 - 2
Artinya :
1 lewatan pada bagian shell
2 lewatan maksimal pada bagian tube

Bagian Shell
IDs = 39 in
n' = 1
B = Antara (1 - 2/10) x IDs (Buku Prarancana Pabrik)
dipilih = 1 maka diperoleh nilai B = 39 in

Bagian Tube

OD = 1 1/2 in

BW = 18

ID = 1 2/5 in

Flow area per tube (a') 1,54 in^2

Surface per lin ft (a") 0,3925 ft^2

Direncanakan :

Disusun = Persegi

Pitch = 2 in

Panjang = 16,0 ft

n = 1

Nt = 307 buah

de = 1,9 in

Evaluasi Perpindahan Panas

Bagian Cooling Water (Tube side)

1. Menghitung Nre Tube

$$a_t = \frac{Nt \times a'_t}{144 \quad n}$$

Kern, tabel 10

in OD 18 BWG

a'_t = 1,540 in^2 (tabel 10)

$$a_t = \frac{307 \times 1,54}{144 \times 1}$$

= 3,2832 ft^2

5. Kecepatan massa (G_t)

$$G_t = \frac{W}{a_t}$$

W CW = 386509 lb

$$G_t = \frac{386509}{3,283}$$

= 117724 lb / jam ft^2

$$\text{velocity} = \frac{Gt}{3600 \quad \rho}$$

= 0,5239 fps

6. pada T_c = 99,50 ^oF

μ = 0,750 cps

= 1,8150 lb / jam.ft

ID = 1,40 in (Kern,Tabel 10)

= 0,1167 ft

$$Nre = \frac{ID \times G_t}{\mu}$$

$$= \frac{0,1167 \times 117724}{1,8150}$$

= 7567,1689

7. Menghitung perpindahan panas

hi = 320 Btu/jam ft^2 ^oF

$$hio = hi \times \frac{ID}{OD}$$

$$= 320 \times \frac{1\ 2/5}{1\ 1/2}$$

= 298,6667 Btu/jam ft^2 ^oF

Bagian Vapor (Shell side)

1. Menghitung Nre Shell

4. Flow area (a_s)

$$a_s = \frac{ID \cdot C' \cdot B}{144\ P_T}$$

ID = 39 in

B = 39 in

P_T = 1,5625

C' = P_T - OD tube

= 1,6 - 1 1/2

= 0,0625

$$a_s = \frac{39 \times 0,06 \times 39}{144 \times 1,5625}$$

= 0,4225 ft^2

5. Kecepatan massa (G_s)

$$G_s = \frac{W}{a_s}$$

W bahan = 14558,2871 lb/jam

$$G_s = \frac{14558,2871}{0,4225}$$

$$= 34457,4843 \quad lb / jam\ ft^2$$

$$G'' = \frac{W\ bahan}{L \times Nt^{2/3}}$$

$$= \frac{14558,2871}{16,0 \times 45,508}$$

$$= 19,9939 \quad lb/jam\ in\ ft$$

2. Menghitung koefisien perpindahan panas

ho = 150 - 300 Btu/jam ft^2 ^oF

(Kondensor Horizontal)

dia,bil nilai ho sebesar :

ho = 250 Btu/jam ft^2 ^oF

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

$$= 99,50 + \frac{250 \quad (\quad 212,00 \quad - \quad 99,50 \quad)}{298,67 \quad + \quad 250}$$

$$= 150,7606 \quad ^oF$$

$$tf = \frac{Tc + tc}{2}$$

$$= \frac{212,00 + 99,50}{2}$$

$$= 155,75$$

Berdasarkan tf, didaptkan : (Kern, 1988)

kf = 1000 Btu/jam ft^2 ^oF

sf = s* = 1

μf = 0,1 cp

Dari fig 12.9 (Kern, 1988) akan didapat :

ho = 200 Btu/jam ft^2 ^oF

Karena nilai ho tersebut berbeda dengan ho trial, jika berbeda tidak boleh lebih dari 20%. Jika lebih dari 20% maka ulangi trial ho.

3. Clean Overall Coefficient (Uc)

10. $U_C = \frac{hio \times ho}{hio + ho}$

$= \frac{298,6667 \times 200}{298,6667 + 200}$

$= 119,7861$ BTU/j ft^2 F

4. Dirt Factor (Rd)

Rd hitung $= \frac{U_C - U_D}{U_C \times U_D}$

$= \frac{119,79 - 50,000}{119,79 \times 50,000}$

$= 0,0117$ J ft^2 F/BTU

Rd perthitungan > Rd data (Kern, 1988)

0,0117 > 0,001 Alat dapat digunakan

5. Pressure Drop

Bagian Shell (Vapor)

Tc = 212 ^oF

μ vapor = 0,0125 cp (Kern, 1988)

= 0,0302 lb/ft jam

de = 1,9 in

= 0,15625 ft

Nre $= \frac{de \times Gs}{\mu \text{ vapor}}$

$= \frac{0,15625 \quad 34457}{0,0302}$

= 178056,4504

f = 0,0024 ft^2/in^2 (Kern, 1988)

N+1 $= 12 \times \frac{l}{B}$ (Kern, 1988)

$= 12 \times \frac{42}{39}$

= 12,923

BM = 18

s = 1

IDs = 3 1/4 ft

Ken eq. 12.47 pg. 273

$$\Delta Ps = \frac{1\ f\ Gs^2\ IDs\ (N+1)}{2\ \ 5\ \ 10\ ^\wedge\ \ 10\ De\ s}$$

= 0,007659627 psi

Bagian Tube (Cooling Water)

Nre = 7567,1689 (Kern, 1988)

didapat f = 0,0005 ft^2/in^2

$$\Delta P_t = \frac{f.Gt^2.L.n}{5{,}22.10^{10}.De.s\ \varphi s}$$ (Kern, 1988)

= 0,018205358 psi

Dari Kern fig.27 pg 837

Gt = 117723,5279 lb/jam ft^2

didapat $\frac{V^2}{2g'}$ = 0,001

$$\Delta Pr = \frac{4n}{s} \times \frac{V^2}{2g'}$$

$$= \frac{4\ \ 1}{1} \times 0{,}001$$

= 0,004 psi

$\Delta P_T = \Delta P_t + \Delta Pr$

= 0,0222 psi

Jadi, $\Delta P_s + \Delta P_T$

0,0299 psi

Dimensi Condensor

Luas Penampung = π/4 D

= 30,615 in^2

= 0,2126 ft

Asumsi H = 2 D

H = 78 in

= 6,5 ft

= 1,9812 m

Menentukan Tekanan Design

P design = Po - Pi

= 14,7 - 1,9
= 12,8 psi

Asumsi P disign 10% lebih besar untuk faktor keamanan

P design = 1,1 x 12,8
= 14,0679 psi

Dipergunakan bahan kontruksi yang terbuat dari Carbon Steel SA-283 grade C (Brownell, 1959)

$f_{allowable}$ = 12650 (Tabel 13.1)

C = 0,125 in

Sambungan las dengan type double welded butt joint

Efisiensi las, E = 0,8

r = 1/2 x 39
= 19 1/2 in

Rumus tebal shell yang digunakan adalah :

$$t_{min} = \frac{P \times ri}{fe - 0{,}6P} + C \quad \text{(Brownell \& Young, 1959)}$$

$$= \frac{(\ 14{,}0679 \times 19{,}5\ )}{((\ 12650 \times 0{,}8\ ) - (\ 0{,}6 \times 14{,}068\ ))} + 1/8$$

= 0,1521 in

Diambil tebal shell = 1/5 in

Menentukan Tebal Tutup, Torispherical

Tutup atas berbentuk standart dished head

OD = ID + 2ts
= 39 + 2 x 1/5
= 39 3/8 in
= 39 3/8 in = 3,28125 ft

rc = 19 2/3 in = 1,64063 ft

Tinggi tutup (h) = $rc - (rc^2 - (D^2/4))^{0,5}$ (Hesse, 1962)

= $1{,}64063 - (\ 2{,}6917 - 2{,}6917\ )^{0,5}$

= 1,640625 ft

Volume dishead = $1{,}1 \times h^2 (3rc - h)$

= $1{,}1 \times 2{,}6917 \times (\ 3 \times 1{,}6406 - 1{,}6406$

= 9,7152 cuft

Bentuk : Flanged and standart dishead head

$$t = \frac{0{,}885 \times P_d \times r_c}{(\ f \times E - 0{,}1P_d\ )} + C \quad \text{(Brownell \& Young, 1959)}$$

Dimana :

P_d = Tekanan desain (psi)
r_c = Crown radius (m)
E = Faktor Pengelasan 80%
t = Tebal dinding minimal (in)

$$t = \frac{0{,}885 \times 14{,}0679 \times 19{,}6875}{(12650 \times 0{,}8) - (0{,}1 \times 14{,}068)} + 0{,}125$$

t = 0,1492 in

Diambil tebal head sebesar 0,1875 in

Spesifikasi condensor

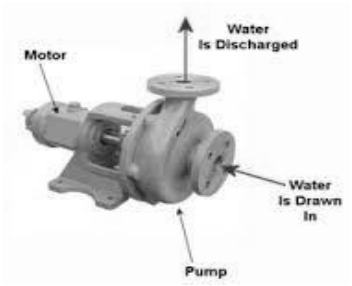
Bagian shell

Diameter	=	3 1/4	ft
Tinggi shell	=	6,5	ft
Tebal Shell	=	0,1875	in
Tebal Tutup	=	0,1875	in

Bagian tube

OD	=	1 1/2	in
BWG	=	18	
ID	=	1 2/5	in
Flow area per tube	=	1,54	in^2
Surface per lin ft	=	0,3925	ft^2
Disusun	=	Persegi	
Pitch	=	2	in
Panjang tube	=	16	ft^2
Jumlah tube	=	307	buah
Bahan	=	Carbon Steel SA-203 Grade C	
Jumlah	=	1	buah

24. POMPA -6 (L-322)



Fungsi = Memindahkan bahan dari evaporator ke kristalizer
Type = Centrifugal Pump
Dasar pemilihan = Sesuai untuk viskositas <10 cP dan bahan liquid

Bahan Masuk

Komponen	Berat	raksi ber	ρ (gr/cm^3)
$Al_2(SO_4)_3(NH_4)_2SO_4.24H_2O$	12637,4499	0,5500	1,65
$Al_2(SO_4)_3$	251,0752	0,0109	2,67
$(NH_4)_2SO_4$	831,3512	0,0362	1,77
H_2SO_4	0,7229	3,E-05	1,97
H_2O	9256,5824	0,4029	1
Total	22977,182	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}5500}{1{,}65} + \frac{0{,}0109}{1{,}6500} + \frac{0{,}0362}{1{,}77} + \frac{0{,}0000}{1{,}97} + \frac{0{,}40}{1}} \times 62{,}43$$

= 81,7925 lb/cuft

Data perhitungan :

Rate bahan = 22977,182 kg/jam
= 50655,954 lb/jam

ρ campuran = 81,7925 lb/cuft
= 1,3103 gr/ml

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

$$= \frac{50655{,}954 \text{ lb/jam}}{81{,}7925 \text{ lb/cuft}}$$

= 619,3229482 cuft/jam
= 10,3220 cuft/menit
= 77,2143 gpm

Perhitungan diameter pipa

Asumsi aliran Turbulen :

Diameter optimum untuk turbulen, Nre >2100 digunakan persamaan :

Di optimum = 3.9 x $qr^{0,45}$ x $\rho^{0,13}$ (Peters, ed.4 pers.15 hal 496)

Dengan : qr = Fluid flow rate , ρ = fluid density ; lb cuft

qr = 10,3220 cuft/menit
= 0,17203 cuft/s

Diameter pipa optimum = 3.9 x $qr^{0,45}$ x $\rho^{0,13}$ (Peters, ed.4 pers.15 hal 496)

= 3,1314 in

Dipilih pipa 3 in, sch 40 (Brownell & Young,1987)

OD = 3,5 in 0,29167 ft

ID = 3,068 in 0,25567 ft

Luas , A = (1/4. π. ID²)

= 0,0513 ft²

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

$$= \frac{81,7925 \text{ lb/cuft}}{62,303 \text{ lb/cuft}} \times 0,996$$

= 1,3076

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

$$= \frac{1,3076 \times 0,001}{0,996}$$

= 0,0013 lb/ft s (berdasarkan sg bahan)

= 1,9537 cp

Kecepatan aliran (V) = $\frac{\text{Rate volumetrik}}{\text{Luas, A}}$ $\frac{\text{cuft/dt}}{\text{ft}^2}$ g = 416061544,8

= 3,3527 ft/dt

$$Nre = \frac{D\ V\ \rho}{\mu} = \frac{0,25567 \times 3,3527 \times 81,7925}{0,0013}$$

= 53404,7474 > 4000 (asumsi turbulen benar)

Menentukan jumlah energi yang hilang

1. Karena pipa lurus

Ditetapkan :

Panjang pipa lurus = 20 ft

Dipilih pipa Galvanized iron = 0,00015 (Geankoplis : 88)

maka harga e/D = 0,001

f = 0,007 (Geankoplis : 88)

gc = 32,174 ft.lbm/dt².lbf

2. Karena friksi (Geankoplis : 88)

Taksiran panjang pipa lurus = 20 ft

4 elbow 90° = 4 x 35 x ID pipa = 35,7933 ft

1 gate valve = 1 x 7 x ID pipa = 1,78967 ft +

Panjang total pipa = 20 ft

Friksi yang terjadi :

1. Friksi karena gesekan bahan dalam pipa :

$$F1 = (2f \times V^2 \times Le)/(gc \times D) = 0{,}38262 \ \frac{\text{ft. lbf}}{\text{lbm}}$$

2. Friksi karena kontraksi dari tangki ke pipa: (α= 1 untuk aliran turbulen)
(K= 0,05 A tangki >>>Apipa)

$$F2 = (K \times V2^2)/(2 \times \alpha \times gc) = 0{,}00873 \ \frac{\text{ft. lbf}}{\text{lbm}}$$ (Peters ed.4 hal 484)

3. Friksi karena ekspansi dari pipa ke tangki:

$$F_3 = \frac{V^2}{2 \times \alpha \times gc} = \frac{\Delta V_2^{\,2} - \Delta V_1^{\,2}}{2 \times \alpha \times gc} = 0{,}17469 \ \frac{\text{ft. lbf}}{\text{lbm}}$$

(V_1 <<<< V_2, maka V_1 dianggap = 0)

4. Friksi karena Elbow 90^o

$$F_4 = \frac{K_f \times V_1^{\,2}}{2} = \frac{0{,}75 \times 11{,}241}{2} = 4{,}2153$$

5. Friksi karena Gate Valve

$$F_5 = \frac{K_f \times V_1^{\,2}}{2} = \frac{0{,}17 \times 11{,}241}{2} = 0{,}9555$$

ΣF(Total Friksi)

$$= F_1 + F_2 + F_3 + F_4 + F_5$$
$$= 0{,}3826 + 0{,}0087 + 0{,}1747 + 4{,}215 + 0{,}9555$$
$$= 5{,}7368 \ \frac{\text{ft.lb}_f}{\text{lb}_m}$$

Persamaan Bernoulli :

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

$P_1 = P_{hidrostatis}$

Diketahui data dari bak pengendapan

Tinggi bahan = 33,8093 ft (Evaporatorr)

ρ bahan = 81,7925 lb/cuft

$P_{hidrostatis}$ = ρ . H

= 81,7925 x 33,8093

= 2765,348169 lb/ft^2

P_2 = 1 atm = 14,7 psi

= 14,7 x 144

= 2116,8000 lbf/ft^2

$\Delta P = P_2 - P_1$

= 2116,80 - 2765,3

= 648,5482 lb_f/ft^2

$$\frac{\Delta P}{\rho} = \frac{648,5482 \ lb_f/ft^2}{81,7925 \ lb_m/ft^3}$$

$$= 7,9292 \ \frac{ft.lb_f}{lb_m}$$

Energi Potensial

asumsi ΔZ = 13,8 ft

Asumsi : g/gc = 1

g percepatan gravitasi = 32 ft/dt^2

gc konstanta gravitasi = 32 ft/dt^2 x lb_m/lb_f

$$\Delta Z \frac{g}{gc} = 13,809 \ ft \times \frac{32 \ ft/dt^2}{32 \ ft.lb_m/dt^2.lb_f}$$

$$= 13,809 \ \frac{ft \ . \ Lbf}{lbm}$$

Energi Kinetik

$$\frac{\Delta V^2}{2 \times gc \times \alpha} = \frac{11,2407}{2 \times 32,2 \times 1}$$

$$= 0,1745 \ \frac{ft.lb_f}{lb_m}$$

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

$$= 7,93 + 13,8093 + 0,1745 + 5,737$$

$$= 27,6498 \ \frac{ft.lb_f}{lb_m}$$

$$hp = \frac{Wf \times qr \times \rho}{550} \quad \text{(Perry, 2008)}$$

$$= \frac{27,65 \times 0,1720 \times 81,7925}{550}$$

$$= 0,7074 \text{ hp}$$

Effisiensi pompa = 23% (Peters & Timmerhaus, fig 14-37)

$$Bhp = \frac{hp}{\eta \text{ motor}} = \frac{0,7074}{0,23} = 3,07560067 \text{ hp}$$

Effisiensi motor = 80% (Peters&Timmerhaus, fig 14-38)

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

$$= \frac{3,0756}{80\%}$$

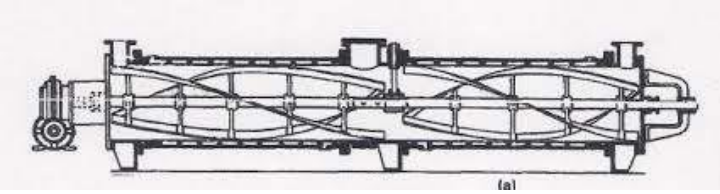
$$= 3,8445 \text{ hp}$$

digunakan power = 4 hp

Spesifikasi :

Fungsi = Memindahkan bahan dari evaporator ke kristalizer
Jenis = Pompa centrifugal
Kapasitas = 22977,182 kg/j
Power = 4 hp
eff. Pompa = 23%
eff. Motor = 80%
Jumlah = 1 pompa
Bahan kontruksi = Carbon Stell

25. KRISTALIZER (X-330)



Fungsi : Memekatkan larutan aluminium amonium sulfat hingga terbentuk kristal
Type : Swensonm - Walker Crystallizer
Bahan masuk

Komponen	Berat	raksi ber	ρ (gr/cm^3)
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12637,44992	0,55	1,65
$Al_2(SO_4)_3$	251,075164	0,0109	2,67
$(NH_4)_2SO_4$	831,3512063	0,0362	1,77

H2SO4	0,7229	3,E-05	1,97
H_2O	9256,5824	0,4029	1
Total	22977,182	1	

$$\rho \text{ campuran} = \frac{1}{\sum \frac{\text{fraksi berat}}{\rho \text{ komponen}}} \times 62$$

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0,5500}{1,65} + \frac{0,0109}{2,67} + \frac{0,0362}{1,77} + \frac{0,0000}{1,97} + \frac{0,4029}{1}} \times 62,43$$

$$= 82,0645 \text{ lb/cuft}$$

Data perhitungan :

Rate bahan = 22977,182 kg/jam
= 50655,954 lb/jam

ρ campuran = 82,0645 lb/cuft
= 1,3147 gr/ml

$$\text{Rate volumetrik} = \frac{\text{rate massa}}{\rho \text{ campuran}} \times \text{waktu tinggal}$$

$$= \frac{50655,954 \text{ lb/jam}}{82,0645 \text{ lb/cuft}}$$

= 617,2701365 cuft/jam
= 10,2878 cuft/menit

Penentuan waktu kristalisasi

t = L/3G

Dimana :

L = Ukuran kristal = 50 mesh = 0,001 m

G = Kecepatan pertumbuhan kristal = 0,000000042 m/s (Perry, 2008)

$$t = \frac{0,001}{3 \times 4,2E\text{-}08}$$

= 7936,507937 dt
= 132,2751323 menit
= 2,204585538 jam

Volume larutan (V) $= \frac{50655,954}{82,0645} \times 2,2046$

$= 1360,8248$ cuft

Ditetapkan volume liquid sebesar 80% volume tangki

Volume kristalizer $= \frac{1360,8248}{0,8}$

$= 1701,03102$ cuft

Untuk kontinuitas proses, digunakan 2 buah kristalizer disusun paralel

volume masing masing keistalizer = 1701,03102 cuft

ditetapkan m = L/D = 3,33 (Hugot, 1972)

Volume kristalizer $= \frac{m\ D^3}{2} \times 1 + \frac{\pi}{4}$

$1701,03102 = \frac{3,33\ D^3}{2} \times 1 + \frac{\pi}{4}$

$D = 10,0708453$ ft

m = L/D, maka didaptkan :

L = 33,53591484 ft

Luas Cooling Area pada kristalizer :

$S = V \times \frac{2 + 4m}{m \times D}$ (Hugot, 1972)

$= 1701,03102 \times \frac{2 + 4\ 3,33}{3,33 \times 10,0708453}$

$= 777,0712488$ ft^2

Power pengaduk pada Swenson - Walker Kristlizer

Power yang digunakan adalah 16 Hp tiap 1000 cuft bahan

Volume bahan = 1360,8248 cuft (Hugot, 1972)

Power Kristalizer $= \frac{1360,8248}{1000} \times 16$

$= 21,77319705$ Hp

Spesifikasi :

Fungsi Memekatkan larutan aluminium amonium sulfat hingga

Type = Swensonm - Walker Crystallizer

Kapasitas = 1701,031 cuft

Diameter = 10,0708453 ft

Panjang = 33,53591484 ft

Luas cooling area = 777,0712488 ft2/ft3

Power = 21,8 Hp

Jumlah = 2 buah

26. CENTRIFUGE (H-340)

Fungsi : Memisahkan kristal basah dan mother liquor
Type : Disk Bowls centrifuge (automatic continous dish cake)
Dasar Pemilihan : Sesuai dengan jenis bahan, effisiensi tinggi
Kondisi Oprasi :
Tekanan = 1 atm
Suhu = 30 ^oC
Waktu proses = Continous

Bahan masuk

Komponen	Berat	raksi ber	ρ (gr/cm^3)
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12637,44992	0,550	1,65
$Al_2(SO_4)_3$	251,075164	0,0109	2,67
$(NH_4)_2SO_4$	831,3512063	0,0362	1,77
H_2SO_4	0,7229	3,E-05	1,97
H_2O	9256,5824	0,4029	1
Total	22977,182	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}5500}{1{,}65} + \frac{0{,}0109}{2{,}67} + \frac{0{,}0362}{1{,}77} + \frac{3{,}E\text{-}05}{1{,}97} + \frac{0{,}4029}{1}} \times 62{,}43$$

= 82,0645 lb/cuft

Data perhitungan :
Rate bahan = 22977,182 kg/jam
= 50655,954 lb/jam
ρ campuran = 82,0645 lb/cuft
= 1,3147 gr/ml

$$\text{Rate volumetrik} = \frac{\text{rate massa}}{\rho \text{ campuran}} \times \text{waktu tinggal}$$

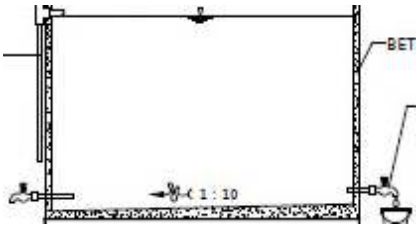
$$= \frac{50655{,}954 \text{ lb/jam}}{82{,}0645 \text{ lb/cuft}}$$

= 617,2701365 cuft/jam
= 10,2878 cuft/menit
= 76,9583 gpm

Spesifikasi
Dari (perry, 2008) berdasarkan rate volumetrik (gallon per minute) dipilih spesifikasi centrifuge sebagai berikut (Perry : T.18-12)

Type	=	Disk Blow Diameter	
Kapasitas	=	76,9583	gpm
Bowl diameter	=	13	in
Kecepatan puturan	=	7500	rpm
Power motor	=	6	hp
Bahan kontruksi	=	Carbon Stell	
Jumlah	=	1 buah	

27. BAK PENAMPUNG MOTHER LIQUOR (F-341)



Fungsi : Menampung impuritis dari clarifier
Type : Bak berbentuk persegi panjang, terbuat dari beton
Bahan masuk :

Komponen	Berat	Fraksi berat	ρ (gr/cm^3)
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	9,9242	0,0010	1,65
$Al_2(SO_4)_3$	246,0537	0,0243	2,67
$(NH_4)_2SO_4$	814,7242	0,0803	1,77
H_2O	9071,4508	0,8944	1
H_2SO_4	0,7085	0,0001	1,97
Total	10142,8613	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0,0010}{1,65} + \frac{0,0243}{2,67} + \frac{0,0803}{1,77} + \frac{0,8944}{1} + \frac{\frac{0,0001}{1,97}}{}} \times 62,43$$

$$= 65,7529 \text{ lb/cuft}$$

Densitas campuran = 65,7529 lb/cuft
Rate Produk = 10142,8613 kg/jam
= 22361,155 lb/jam
Waktu tinggal = 24 jam
ρ campuran = ρ bahan

$$\text{Rate volumetrik} = \frac{\text{rate massa}}{\rho \text{ campuran}} \times \text{waktu tinggal}$$

$$= \frac{22361,155 \text{ lb/jam}}{65,7529 \text{ lb/cuft}} \times 24 \text{ jam}$$

$$= 8161,883484 \text{ cuft}$$

Dimisalkan :
Panjang = 4 X m
Lebar = 3 X m
Tinggi = 2 X m

Volume bak penampung (direncanakan 80% terisi impuritis) :

$$= \frac{8161,883484}{0,8}$$

$$= 10202,35436 \text{ cuft}$$

Volume bak penampung = p x l x t
10202,35436 = 4 X x 3 X x 2 X
10202,35436 = 24 X^3
X = 7,5191

Maka,
Panjang = 4 X m = 4 x 7,5191 = 30,076 ft
Lebar = 3 X m = 3 x 7,5191 = 22,5572 ft
Tinggi = 2 X m = 2 x 7,5191 = 15,0381 ft

Check volume :
Volume bak = p x l x t
= 30,0762 x 22,5572 x 15,0381

= 10202,3544 cuft ≈ 10202,3544 cuft (memenuhi)

Spesifikasi :

Fungsi	=	Menampung mother liquor dari centrifuge		
Kapasitas	=	10202,3544 cuft		
Bentuk	=	Empat persegi panjang terbuka		
Ukuran	=	Panjang	=	30,0762 ft
		Lebar	=	22,5572 ft
		Tinggi	=	15,0381 ft
Bahan kontruksi	=	Beton		
Jumlah	=	1 buah		

28. SCREW CONVEYOR (J-342)

Fungsi	:	Untuk mengangkut kristal ke Rotary Dryer
Type	:	Plain sponts or chutes
Dasar Pemilihan	:	Umum digunakan untuk padatan dengan sistem tertutup

Bahan masuk

Komponen	Berat	Fraksi be	ρ (gr/cm^3)
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12627,52575	0,9839	1,65
$Al_2(SO_4)_3$	5,021503279	0,0004	2,67
$(NH_4)_2SO_4$	16,62702413	0,0013	1,77
H_2SO_4	0,014458766	1E-06	1,97
H_2O	185,1316489	0,0144	1
Total	12834,320	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0,9839}{1,65} + \frac{0,0004}{2,67} + \frac{0,0013}{1,77} + \frac{1,E-06}{1,97} + \frac{0,0144}{1}} \times 62,43$$

= 102,0767 lb/cuft

Data perhitungan :

Rate bahan	=	12834,320	kg/jam
	=	28294,799	lb/jam
ρ campuran	=	102,0767	lb/cuft
	=	1,6353	gr/ml

$$\text{Rate volumetrik} = \frac{\text{rate massa}}{\rho \text{ campuran}} \times \text{waktu tinggal}$$

$$= \frac{28294{,}799 \text{ lb/jam}}{102{,}0767 \text{ lb/cuft}}$$

=	277,191658	cuft/jam
=	4,6199	cuft/menit
=	34,5590	gpm

dari (Badger, 1955), bahan termasuk kelas D dengan F = 2,5

Power motor = $\frac{CLWF}{33000}$ (Badger: 360)

Dengan :

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

Direncanakan panjang screw conveyor = 30 ft

$$\text{Power} = \frac{(\ 4{,}6199 \times 30 \times 102{,}077 \times 2{,}5\ )}{33000}$$

= 1,07177 hp

Karena power < dari 2 hp, maka :

Power = 2 x 1,07177

= 2,1435 ≈ 2,5 hp

Dari (Perry : Tabel 21-6) dipilih screw conveyor :

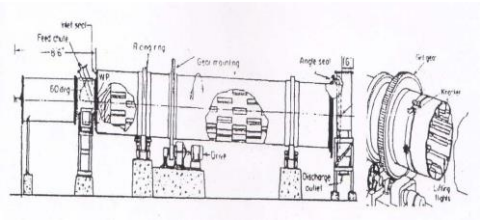
Kapasitas	=	277,1917	cuft/jam
Diameter	=	9	in
Kecepatan putaran	=	40	rpm

Spesifikasi :

Fungsi	=	Untuk mengangkut kristal ke Rotary Dryer	
Type	=	Plain sponts or chutes	
Kapasitas	=	277,1917	cuft/jam
Panjang	=	30	ft
Diameter	=	9	in
Kecepatan putaran	=	40	rpm

power = 2,5 hp
Jumlah = 1 buah

29. ROTARY DRYER (B-350)



Fungsi = Mengeringkan bahan dengan bantuan udara panas
Dasar Pemilihan = Sesuai untuk pengeringan padatan
Kondisi Operasi = Tekanan : 1 atm
Suhu : 80 ^{o}C
Waktu proses : Waktu melewati (time of passes)

Bahan masuk

Komponen	Berat	Fraksi berat	ρ (gr/cm^3)
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12627,5258	0,9839	1,65
$Al_2(SO_4)_3$	5,0215	0,0004	2,67
$(NH_4)_2SO_4$	16,6270	0,0013	1,77
H_2SO_4	0,0145	1,E-06	1,97
H_2O	185,1316	0,0144	1
Total	12834,320	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}9839}{1{,}65} + \frac{0{,}0004}{2{,}67} + \frac{1{,}E\text{-}03}{1{,}77} + \frac{1{,}E\text{-}06}{1{,}97} + \frac{0{,}0144}{1}} \times 62{,}43$$

= 102,0767 lb/cuft

Data perhitungan :
Dari neraca massa dan neraca panas :

Rate bahan = 12834,320 kg/jam
= 28294,799 lb/jam
ρ campuran = 102,0767 lb/cuft
= 1,6353 gr/ml
Total Panas = 1597637,025 kkal/jam
= 6336228,44 Btu/jam

Kristal Basah
T = 35 ^oC
95 ^oF

Kristal Kering
T = 105 ^oC
221 ^oF

Rotary Dryer

Udara Panas Keluar
T = 98,25 ^oC
208,85 ^oF

Udara Panas Masuk
T = 120 ^oC
248 ^oF

Δt_1 = 248,00 - 208,85 = 39,15 $^\circ F$
Δt_2 = 221,00 - 95,000 = 126 $^\circ F$

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

$$= \frac{126 - 39,15}{\ln \frac{126}{39,15}}$$

= 74,3 $^\circ F$
= 296,65 ^oK

Diameter Rotary Dryer, D = 1 - 3 m (Ulrich : T.4-10)
Dipilih diameter = 1 m = 3,28084 ft
Ratio L/D = 4- 6
Dipilih = 4
Jadi panjang dryer = L/D = 4
L = 4 m

Putaran Rotary Dryer
N x D = 23 - 35
Diambil N x D = 32

$$N = \frac{32}{3,28084} = 9,7536 \text{ rpm}$$

Perhitungan Area of drum, A

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

= 0,7850 m

Pehitungan waktu tinggal : (Perry : pers 12-55)

$$\theta = \frac{0,23\ L}{S\ N^{0,5}\ D} \pm 0,6\frac{B\ L\ G}{F}$$

Dengan :

θ	=	Time of passes	(menit)	
L	=	Panjang drum	4	m
			13,1234	ft
S	=	Slope drum	5	ft/ft
N	=	Speed	9,7536	rpm
D	=	Diameter drum	1	m
			3,28084	ft
B	=	Konstanta material	0,122	
G	=	Rate massa udara	0,5 - 5	kg/m^2 s
F	=	Rate solid	lb solid/j.ft^2	
			28294,799	lb/jam
			471,5799902	lb/menit
DP	=	Ukuran partikel	35 mesh	= 1680

$$\theta = \frac{0,23\ L}{S\ N^{0,5}\ D} \pm 0,6\frac{B\ L\ G}{F}$$

$$= \frac{0,23\ \ 4}{5\ \ 3,1231\ \ 1} \pm 0,6\frac{0,122\ \ 4\ \ 1}{471,5799902}$$

= 0,0595 menit

≈ 0,06 menit

Perhitungan Tebal Shell Drum

Rotary drum memakan shell dari carbon steel SA-515 grade 55 dengan stress allowable = 13700 psi (Perry, 2008)

ρ = 102,08 lb/cuft

Perhitungan fight rotary drum

Panjang drum = 4 m

Slope rotary dryer (S) = 0 - 8 cm/m (Perry : 12-56)

diambil, S = 5 cm/m

maka :

tg α = 5

sudut rotary, α = 26,567

slope actual = 5 cm/m x 4 m

= 20 cm

= 0,2 m

Power Penggerak :

$$BHP = \frac{N\,(4{,}75\,dw + 0{,}1925\,DW + 0{,}33\,W)}{100000}$$ (Perry : 12-60)

Keterangan :

BHP	=	Brake Horse Power yang dibutuhkan
d	=	diameter shell (ft)
D	=	diameter riding ring = (d+2), ft
w	=	berat material, lb
W	=	berat total rotary dryer, lb
N	=	putaran rotary dryer, rpm

Berat Total Rotary Dryer :

Berat Silinder :

$$Ws = \frac{\pi}{4}\,(D2^2 - D1^2)\,L\,\rho$$

Keterangan :

D2	=	diameter luar silinder shell	3,3225	ft
D1	=	diameter dalam silinder shell	3,2808	ft
ρ	=	densitas steel	489	lb/cuft
L	=	panjang rotary dryer	13,123	ft

$$Ws = \frac{\pi}{4}\,(D2^2 - D1^2)\,L\,\rho$$

$$Ws = \left(\frac{\pi}{4}\,11{,}0391 - 10{,}7639\right)\,13{,}123\,\,489$$

= 1386,042076 lb

628,6981519 kg

Berat isolasi

$$Ws = \frac{\pi}{4}\,(D3^2 - D1^2)\,L\,\rho$$

Keterangan :

D3	=	diameter luar isolasi	3,3225	ft	
ρ	=	densitas isolasi	13	lb/cuft	(magnesia 85%) (Perry, 2008)

$$Wt = \frac{\pi}{4}\,(D3^2 - D1^2)\,L\,\rho$$

= 36,8477 lb

Berat flight :
$W_f = n\ L\ h\ t\ \rho$

Keterangan :
n = jumlah flight 2 D - 3,5D (Perry, 2008)
diambil n = 2 D
2 3,28084 = 6,5617 ≈ 7 buah
h = tinggi flight 1/8 D - 1/12 D
diambil h = $\frac{1}{10}$ x 3,28084 = 0,3281 ft
t = tebal flight π D/12
π $\frac{3,28084}{12}$ = 0,8585 ft
Wf = 7 x 13,1234 x 0,32808 x 0,8585 x 489
= 12652,32812 lb

Berat material :
W = rate feed x e
= 28294,79941 x 0,1 menit x $\frac{1}{60}$
= 28,29479941 lb

Berat Gear

$$W_g = \frac{\pi}{4}\ b\ (\ D^2\ -\ d^2\ )\ \rho$$

Keterangan :
b = lebar permukaan gear
= 2,38 Pc + 0,25 (Hasse, 1962)
Dimana Pc = circulair = 1,75 - 2 in
diambil Pc = 2 in
Jadi, b = 2,38 2 + 0,25
5,01 in
d = diameter luar shell rotary dryer
= 3,32251 ft
ρ = densitas cast iron
= 450 lb/cuft (Perry, 2008)

$$W_g = \frac{\pi}{4} \times \frac{5,01}{12} \times \left(\frac{108}{12} - 11,039 \right) 450$$
= 10317,972 lb

Berat riding ring :

$$Wr = 2 \times \frac{\pi}{4} \times b \left(D^2 - d^2 \right) \rho$$

Keterangan :

b = 5,01 in

d = 3,32251 ft

D = diameter riding ring (Perry, 2008)

= d + 2

= 5,32251 ft

$$Wr = 2 \times \frac{\pi}{4} \times \frac{5,01}{12} \times (28,329 - 11,039) \; 450$$

= 5099,931103 lb

Jadi, berat total rotary dryer :

= 1386,04 + 36,848 + 12652 + 28,29 + 10318 + 5099,931103

= 29521,4158 lb

Power Penggerak (BHP)

$$BHP = \frac{N (4,75\, dw + 0,1925\, DW + 0,33\, W)}{100000}$$

= 3,943940225 hp

Effisiensi motor = 80%

$$\text{Power Motor} = \frac{3,94394}{0,8}$$

= 4,92993 hp

≈ 5 hp

Spesifikasi :

Kapasitas	=	12834,320 kg/jam
Isolasi	=	Batu isolasi
Diameter	=	1 m
Panjang	=	4 m
Sudut Rotary	=	26,567 ^{o}
Time of Passes	=	0,06 menit
Kecepatan putaran	=	9,7536 rpm
Tinggi radial flight	=	0,32808 ft
Jumlah flight	=	7 buah
Power	=	5 hp
Jumlah	=	1 buah

30. CYCLONE (H-354)

Fungsi : Memisahkan padatan dari aliran udara panas
Type : Cyclone Separatoe
Dasar pemilihan : Efektif dan sesuai dengan jenis bahan

Rate udara = 248,6954114 kg/jam
548,2788778 lb/jam
BM udara = 28,84
ρ udara = 0,081 lb/cuft

$$\text{Rate volumetrik} = \frac{\text{rate massa}}{\rho \text{ udara}}$$

$$= \frac{548{,}279 \text{ lb/jam}}{0{,}0810 \text{ lb/cuft}}$$

= 6768,875035 cuft/jam
= 1,880243065 cuft/detik

Bahan masuk

Komponen	Berat	Fraksi be	ρ (gr/cm^3)
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	126,275258	0,5078	1,65
$Al_2(SO_4)_3$	0,050215	2,E-04	2,67
$(NH_4)_2SO_4$	0,166270	7,E-04	1,77
H_2SO_4	0,000145	6,E-07	1,97
H_2O	122,203524	0,4914	1
Total	248,695	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}5078}{1{,}65} + \frac{0{,}0002}{2{,}67} + \frac{0{,}0007}{1{,}77} + \frac{6{,}E\text{-}07}{1{,}97} + \frac{0{,}4914}{1}} \times 62{,}43$$

= 78,0805 lb/cuft

Berat solid = 248,6954 kg/jam
548,2789 lb/jam
0,1523 lb/detik

ρ solid = 78,0805 lb/cuft
ρ udara = 0,0810 lb/cuft (Perry, 2008)

Volumetrik solid = $\frac{\text{rate massa}}{\rho \text{ campuran}}$ x waktu tinggal

= $\frac{548,279 \text{ lb/jam}}{78,0805 \text{ lb/cuft}}$

= 7,02197078 cuft/jam

= 0,0020 cuft/detik

Total volumetrik bahan = 0,00195 + 1,88024307

= 1,882193613 cuft/det

Asumsi time passes = 2 detik

Volume bahan = Total volumetrik bahan + time passes

= 1,882193613 x 2

= 3,764387226 cuft

Berdasarkan (Ulrich, 1984) H/D = 4-6

diambil H/D = 5

Volume = $\frac{1}{4}$ π D^2 H

3,76439 = $\frac{1}{4}$ π D^2 5D

3,76439 = 3,925 D^3

D^3 = 0,959079548

D = 0,9862 ft

= 11,8340 in

Maka H = 5 D

H = 5 0,9862

= 4,9308 ft

= 59,1702 in

Didapatkan :

Dc	=	11,834	in		
Bc	=	1/4	Dc	=	2,959 in
De	=	1/2	Dc	=	5,917 in
Hc	=	2	Bc	=	5,917 in
Lc	=	2	Dc	=	23,67 in
Sc	=	1/8	Dc	=	1,4793 in
Zc	=	2	Dc	=	23,67 in
Jz	=	1/4	Dc	=	2,959 in

Area Cyclone = $\frac{1}{4}$ π D^2

= 0,76343619 ft^2

Kecepatan bahan, Vc = $\frac{\text{Total volumetrik bahan}}{\text{Area Cyclone}}$

= $\frac{1,8822}{0,7634}$

= 2,4654 ft/dt

= 0,7515 m/dt

Suhu udara masuk cyclone 100 ^oC

212 ^oF

$$Dpc = \left(\frac{9 \mu Bc}{\pi Ns Vc (\rho s - \rho)} \right) 0,5$$

Keterangan :

Dpc = Ukuran partikel yang bisa lolos dari ayakan
Dpc = Ukuran partikel yang diijinkan lolos
Bc = besar inet dust (ft)
Ne = jumlah belokan yang dilalui udara
Vc = kecepatan gas masuk cyclone (ft.dt)
ρs = densitas bahan (lb/cuft
ρ = densitas gas (lb/cuft)
μ = viskositas gas (lb/ft dt)

μ udara = 0,021 cp (Kern, 1988)
Ns = 0,2 (Perry, 2008)

Sehingga :

$$Dpc = \left(\frac{9 \mu Bc}{\pi Ns Vc (\rho s - \rho)} \right) 0,5$$

$$= \left(\frac{9 \text{ x } 0,021 \text{ x } 2,959}{3 \text{ x } 0,2 \text{ x } 2,465 \quad 77,999} \right) 0,5$$

= 0,0680 ft

Perencanaan tabel shell dan tutup

Bahan kontruksi dipilih Carbon Steel SA-283 grade C (Brownel, 1959)

$f_{allowable}$ = 12650 (Tabel 13.1)

C = 1/8 in

Sambungan las dengan type double welded butt joint

Efisiensi las, E = 0,8

tekanan desaign = 1 atm = 14,7 psi

r = 1/2 x D

= 1/2 x 11,8

= 5,91702 in

Rumus tebal shell cilindrical shell :

$$t_{min} = \frac{P \times ri}{fe - 0{,}6P} + C$$ (Brownell & Young, 1959)

$$= \frac{(\ 14{,}7 \times 5{,}9170\ )}{((\ 12650 \times 0{,}8\ ) - (\ 0{,}6 \times 14{,}700\ ))} + 1/8$$

= 0,1336 in

Diambil tebal shell = 0,1875 in

Tebal tutup atas :

Karena cyclone pada kondisi atmospheric, maka digunakan

tebal tutup = 1/4 in

Tutup bawah :

$$tc = \frac{P \times D}{2 \cos 60\ (f E - 0{,}6P_d)} + C$$

dengan α = 30^o (sudut conis)

$$tc = \frac{(\ 14{,}7 \times 11{,}8340\ )}{2 \cos 30\ ((\ 12650\ 0{,}8\ ) - (\ 1 \times 14{,}7\ ))} + 1/8$$

t = 0,1808 in

Diambil tebal conis 0,1875 in

Spesifikasi :

Fungsi	=	Memisahkan padatan dari aliran udara panas		
Type	=	Cyclone Separator		
Kapasitas	=	548,2789	lb/jam	
Ukuran	=	Bc	=	2,959 in
		De	=	5,917 in
		Hc	=	5,917 in
		Lc	=	23,668 in
		Sc	=	1,479 in
		Zc	=	23,668 in
		Jz	=	2,959 in
Tebal shell	=	0,1875 in		
Tebal tutup atas	=	1/4 in		
Tebal tutup bawah	=	0,1875 in		
Bahan kontruksi	=	Carbon Steel SA-283 Grade C		
Jumlah	=	1 buah		

31. BLOWER (E-351)

Fungsi : Untuk menghembuskan udra menuju ke heater pada rotary dryer

Perhitungan :

Rate udara = 63701,63576 kg/jam
140437,9002 lb/jam

BM udara = 28,84

ρ udara = 0,081 lb/cuft

Pressure drop diambil = 0,5 psi

dimana : P_2 = 8 psi (pery.2008)

P_1 = 14,7 in H20

Volumetrik udara (Q) = $\frac{\text{rate massa}}{\rho \text{ campuran}}$

= $\frac{140437,900 \text{ lb/jam}}{0,0810 \text{ lb/cuft}}$

= 1733801,237 cuft/jam

= 28896,687 cuft/menit

Power untuk menghembuskan udara :

Hp = 0,000157 x Q x ΔP (Perry, 2008)

= 0,000157 28896,687 6,7

= 30,39642536 hp

Effisiensi pompa = $\frac{\text{HP blower}}{\text{HP shaft}}$

Effisiensi blower = 70%

HP shaft = $\frac{\text{HP blower}}{\eta \text{ pompa}}$

= $\frac{30,3964}{70\%}$

= 43,4235 hp

digunakan power = 43,4 hp

Spesifikasi :

Fungsi = Untuk menghembuskan udara menuju heater

Type = Centrifugal blower

Kapasitas = 28896,687 cuft/menit

HP shaft = 43 hp

Bahan kontruksi = Carbon Steel

Jumlah = 1 buah

32. MOLECULAR SIEVE TRAY (D-352)

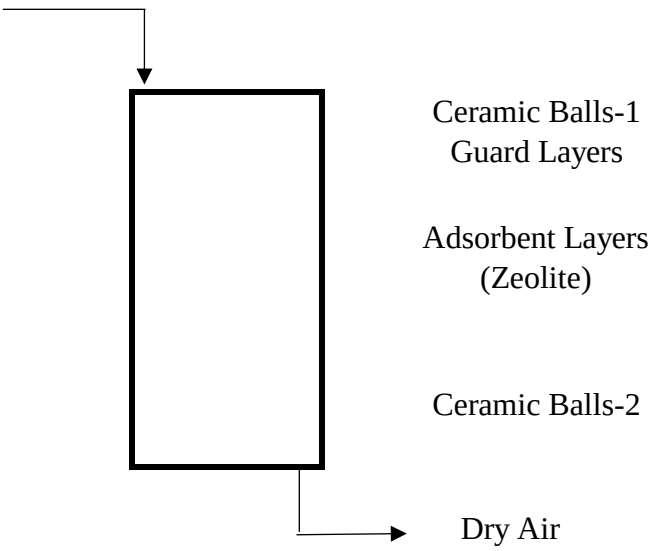
Fungsi	:	Menyerap air dalam udara luar yang masuk				
Tipe	:	*Fixed Bed Column Molecular Sieve Air Dryer*				
Dasar Pemilihan	:	Dew point yang dihasilkan lebih rendah dan effective capacity				
Kondisi Operasi	:	- Tekanan	=	1	atm	
		- Suhu	=	30	^{o}C	
		- Waktu Proses	=	1	jam	

Perhitungan:

Udara Masuk	=	63701,6358	kg/jam			
	=	140436,6262	lb/jam			
Densitas	=	62,4280	lb/cuft			
Rate Volumetri	=	2249,5775	cuft/jam			
Volume Fluida	=	Rate Volumetrik	cuft/jam	x	t (waktu tinggal)	
	=	2249,5775	cuft/jam	x	1	jam
	=	2249,577532	cuft			

(KLM Technology Group)

Desain Column :



(Design By Merichem Gas Processing & LNG)

Keterangan :

Ceramic Balls-1	=	0,5	in	
Guard Layers	=	0,125	in	
Adsorbent Layers	=	0,1875	in	
Ceramic Balls-2	=	0,875	in	+
Total Height	=	1,6875	in	

Scale Up = 168,75 in
= 4,2863 m

Untuk tinggi ruang kosong (outlet distributor + inlet) diasumsik 65% dari tinggi bahan isian.
Tinggi Ruang Kosong = 2,7861 m

Maka diperoleh total tinggi kolom = 7,0723 m
Asumsi L/D = 4
D = 1/4 L
= 1,7681 m

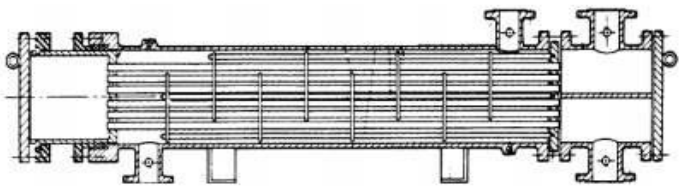
Kebutuhan Zeolit:
H = 18,75 in
= 0,4763 m
D = 1,768 m

Sehingga, volume zeolit yang dibutuhkan :
Volume Zeolit = 1/4 x π x D^2 x H
= 1/4 x 3,14 x 3,126 x 0,47625
= 1,17 m^3
= 1,17 m^3/jam
= 9256,20 m^3/tahun

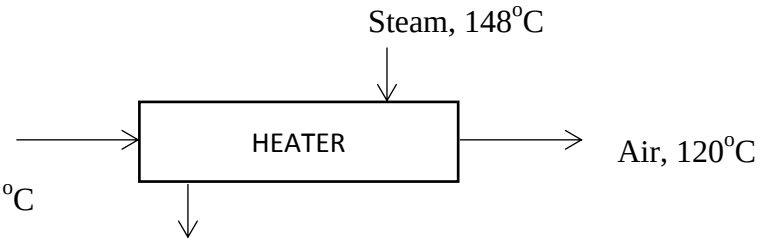
Spesifikasi:

Tinggi Kolom	:	7,072 m
Diameter Kolom	:	1,768 m
Karakteristik Adsorben		
Jenis Adsorben	:	Molecular Sieve 4A
Bentuk	:	Pellet
Bulk Density	:	40 - 45 lb / cuft
Ukuran Partikel	:	1,6 mm - 6 mm
Spesific Heat	:	0,24 BTU / lb.^oF
Kebutuhan Zeolit	:	1,17 m^3/tahun

33. HEATER -3 (E-353)



Fungsi : Memanaskan udara menuju rotary dryer
Tipe : 1-2 *Shell and tube heat exchanger (Fixed tube)*
Dasar Pemilihan : Umum digunakan pada kapasitas yang besar
Kondisi Operasi : - Tekanan = 1 atm
- Temperatur = 120 ^oC
- Waktu proses : *Continue*



Kondisi Proses :

- **Fluida Dingin**

T masuk (t_1) = 30,00 ^oC = 86,000 ^oF = 303,15 K
T keluar (t_2) = 120 ^oC = 248 ^oF = 393,15 K
P masuk = 1 atm = 14,700 psia
P keluar = 1 atm = 14,700 psia

- **Fluida Panas**

T masuk (T_1) = 148 ^oC = 298,40 ^oF = 421,15 K
T keluar (T_2) = 148 ^oC = 298,40 ^oF = 421,15 K
P masuk = 4,5 atm = 66,150 psia
P keluar = 4,5 atm = 66,150 psia

Fluida dingin (^oF)		Fluida panas (^oF)	diff
248,00	Higher Temp	298,40	50,40
86,00	Lower Temp	298,40	212,40
162,00	diff	0	162,00

Perhitungan :

1. Data dari neraca Massa dan neraca panas diperoleh :

Panas yang dibutuhkan; Q = 478385,6510 kkal/jam
= 1897277,4920 Btu/jam
Steam yang digunakan : W_{steam} = 944,9892 kg/jam
= 2083,3420 lb/jam
Wfluida dingin = 63701,6358 kg/jam
= 140437,9002 lb/jam

2. Log Mean Temperature Difference :

Δt_1 = 298,40 - 248,00 = 50,4 ˚F

Δt_2 = 298,40 - 86,000 = 212,4 ˚F

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

$$= \frac{212,4 - 50,4}{\ln \frac{212,4}{50,4}}$$

= 112,6 ˚F

$$R = \frac{T1 - T2}{t2 - t1} = \frac{298,40 - 298,40}{248 - 86}$$

= 0,0000

$$S = \frac{t2 - t1}{T1 - t1} = \frac{248 - 86}{298 - 86}$$

= 0,763

F_T = 0,75 **(Kern fig 18)** (untuk 1-2 shell and tube)

$\Delta T = F_T$ x LMTD

= 0,75 x 112,6189

= 84,4641 ˚F

3. Tc dan tc

Tc = Tav steam

$$Tc = \frac{T_1 + T_2}{2} = \frac{298,40 + 298,40}{2}$$

= 298,40 ^oF (μ = 0,014 cp)

tc = tcav bahan

$$tc = \frac{t_1 + t_2}{2} = \frac{86,00 + 248,00}{2}$$

= 167,00 ^oF (μ = 0,025 cp)

Trial Ud

Hot Fluid = Steam

cold Fluid = Air

Ud = 5-50 Btu/ft^{2}j^{o}F **(tabel 8 Kern hal.840)**
Dipilih Ud = 40 Btu/ft^{2}j^{o}F

$$A = \frac{Q}{UD \times \Delta T}$$
$$= \frac{1897277,4920}{40 \times 84,46}$$
$$= 561,5630 \text{ ft}^2$$

Direncanakan dengan spesifikasi
Digunakan tube dengan ukuran :
OD, BWG = 3/4 in , 12 BWG
Pitch = 1 in square pitch
Panjang Tube L = 6 ft
Dari kern tabel 10 hal 843 diperoleh :
ID = 0,532 in
a't flow area per tube = 0,223 in^2
a" surface per lin = 0,1963 ft^2

$$\text{Jumlah Tube (Nt)} = \frac{A}{a'' \times L}$$
$$= \frac{561,563}{0,1963 \times 6}$$
$$= 476,79 \text{ buah}$$
digunakan Nt = 553 buah
Dari Kern, tabel 9 hal 842, untuk 3/4 in 12 BWG 1 square pitch ;
Tube passes = 1
didapatkan :
ID Shell = 29 in (tabel 9, Kern)
pitch = 1 in square

Fluida Panas (Tube side)	Udara (Shell side)
Steam	
4. Flow area (a_b)	**4**. Flow area (a_s)
$a_t = \frac{Nt \times a'_t}{144 \; n}$	$a_s = \frac{ID \cdot C' \cdot B}{144 \; P_T}$
	ID = 29 in
Kern, tabel 10	asumsi : B = ID / 5
3/4 OD 12 BWG	= 5,8 in
a'_t = 0,223 in^2 (tabel 10)	P_T = 1

$a_t = \frac{553 \times 0,22}{144 \times 1}$

$= 0,8564 \ ft^2$

5. Kecepatan massa (G_t)

$G_t = \frac{W}{a_t}$

Wsteam = 2083,34 lb

$G_t = \frac{2083,34}{0,856}$

$= 2432,725 \ lb / jam \ ft^2$

6. pada T_c = 298 ^oF

μ = 0,014 cps

= 0,0339 lb / jam.ft

D_i = 0,53 in (Kern,Tabel 1

= 0,0443 ft

$Re_t = \frac{D_i \times G_t}{\mu}$

$= \frac{0,0443 \times 2432,725}{0,0339}$

= 3183,3183

C' = P_T - OD tube

= 1 - 3/4

= 0,25

$a_s = \frac{29 \times 0,25 \times 5,8}{144 \times 1}$

$= 0,2920 \ ft^2$

5. Kecepatan massa (G_s)

$G_s = \frac{W}{a_s}$

W fluida 140437,9002 kg

$G_s = \frac{140437,9002}{0,2920}$

$= 480928,8379 \ lb / jam \ ft^2$

tc = 167 ^oF

μ = 0,025 cps

= 0,0605 lb / jam.ft

De' = 0,95 in Kern, fig. 28

= 0,0792 ft

$Re_s = \frac{D_e \times G_s}{\mu}$

$= \frac{0,0792 \times 480928,8379}{0,0605}$

= 629314,5950

7. j_H = 400 (fig. 24)

8. pada t_c = 167 ^oF

Cp = 0,0250 Btu / lb.^oF (fig 2)

k = 0,74 Btu/jam $ft^{2o}F$ (tabel 4)

$\left(\frac{Cp.\mu}{k}\right)^{1/3} = \frac{0,025 \times 0,06}{0,74}$

= 0,1269

μw = 1 (standart)

$\varphi t = (\mu/\mu w)^{0,14}$

= 0,675

9. Hio untuk kondensasi steam hio = 1500 Btu/j ft^2 ^oF (Kern;168)	9'. ho $ho = J_H \frac{k}{De} \left(\frac{Cp.\mu}{k}\right)^{1/3} \varphi t$ $= 400 \frac{0,74}{0,0792} 0,1269 \quad 0,68$ = 320,393 Btu/hr.ft^2.^oF

10. $U_C = \frac{hio \times ho}{hio + ho}$

$= \frac{1500 \times 320,3930}{1500 + 320,3930}$

= 264,0031 BTU/j ft^2 F

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

$= \frac{1897277,492}{561,563 \times 84,464}$

= 40,000 BTU/j ft^2 F

Rd hitung $= \frac{U_C - U_D}{U_C \times U_D}$

$= \frac{264,00 - 40,000}{264,00 \times 40,000}$

= 0,0212 J ft^2 F/BTU

Rd perthitungan > Rd data

0,0212 > 0,003 maka dari segi faktor kekotoran memenuhi syarat

Pressure Drop

Tube Side Steam	Shell side Udara
1. Re_t = 3183,318 f = 0,00030 ft^2/in^2 *(Kern,Fig 26)* s = 0,0360 (tabel 6)	1'. Re_s = 629314,59 f = 0,001 ft^2/in^2 *(Kern,Fig 29)* s = 1,000
2. $\Delta P_t = \frac{f.Gt^2.L.n}{5,22.10^{10}.De.s\,\varphi s}$ 0,0003 2433 6,000 2,0	2'. N+1 = 12 L / B = 12 6 / 6 = 12

$5,22.10^{10}$ 0,044 0,0360 1

= 0,0003 psi

3. Gt = 2432,7 lb/j ft^2

$\frac{V^2}{2g'}$ = 0,001 (Kern, 1988)

4. $\Delta Pr = \frac{4n}{s} \times \frac{V^2}{2g'}$

$= \frac{4 \quad 2}{0,0360} \times 0,0010$

= 0,222 psi

$\Delta P_T = \Delta P_t + \Delta Pr$

= 0,2225 psi

$\Delta P_T < 2$ psi

D_s = 29,000 / 12

= 2,417 ft

3'. $\Delta P_s = \frac{f.Gs^2.Ds.(N+1)}{5,22.10^{10}.De.s.\varphi s}$

$= \frac{0,001 \quad 480929 \quad 2,417 \quad 12,4}{5,22.10^{10} \quad 0,079 \quad 1,000 \quad 1}$

= 1,6791 psi

$\Delta P_T < 10$ psi

Rd perhitungan > Rd data (Kern ; T 12)

0,0212 > 0,0030 maka dari segi faktor kekotoran memenuhi syarat

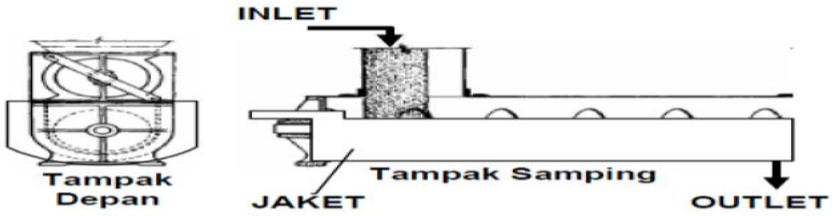
$\Delta P_T < 10$ psi P shell = 1,679075 psi memenuhi

$\Delta P_T < 2$ psi P tube = 0,2225 psi memenuhi

Spesifikasi :

Fungsi : Memanaskan udara menuju rotary dryer
Type : Shell and tube, 1-2 exchanger (Fixed tube)
Dasar pemilihan : Umum digunakan dan mempunyai range perpindahan panas yang besar
Shell side :
ID : 29,00 in
B : 5,80 in
n : 2 passes
Tube side :
Nt : 553 buah
L : 6 ft
OD : 3/4 in
BWG : 12
n : 2 passes
Pitch : Square pitch 1"
Heat exch, area A : 561,563 ft2
Jumlah heat exch : 1
Bahan konstruksi : Carbon Steel

34. COOLING CONVEYOR (J-355)



Fungsi : Untuk mendinginkan kristal
Type : Plain sponts or chutes
Dasar Pemilihan : Umum digunakan untuk padatan dengan sistem tertutup

Bahan masuk

Komponen	Berat	raksi ber	ρ (gr/cm^3)
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12626,263	0,9933	1,65
$Al_2(SO_4)_3$	5,021001129	0,0004	2,67
$(NH_4)_2SO_4$	16,62536142	0,0013	1,77
H_2SO_4	0,01445732	1E-06	1,97
H_2O	62,92812488	0,005	1
Total	12710,852	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}9933}{1{,}65} + \frac{0{,}0004}{2{,}67} + \frac{1{,}E\text{-}03}{1{,}77} + \frac{1{,}E\text{-}06}{1{,}97} + \frac{0{,}0050}{1}} \times 62{,}43$$

$$= 102{,}7036 \text{ lb/cuft}$$

Data perhitungan :

Rate bahan = 12710,852 kg/jam
= 28022,598 lb/jam
ρ campuran = 102,7036 lb/cuft
= 1,6453 gr/ml

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

$$= \frac{28022{,}598 \text{ lb/jam}}{102{,}7036 \text{ lb/cuft}}$$

= 272,8491619 cuft/jam
= 4,5475 cuft/menit
= 34,0176 gpm

dari (Badger, 1955), bahan termasuk kelas D dengan F = 2,5

Power motor = $\frac{CLWF}{33000}$

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

Direncanakan panjang screw conveyor = 30 ft

Power = $\frac{(\ 4,5475 \times 30 \times 102,704 \times 2,5\ )}{33000}$

= 1,06146 hp

Karena power < dari 2 hp, maka : 0

Power = 2 x 1,06146

= 2,1229 ≈ 2 hp

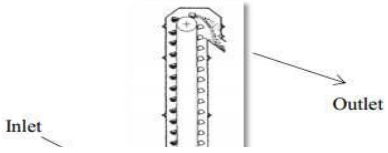
Dari (Perry : 21-6) dipilih screw conveyor :

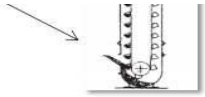
Kapasitas = 272,8492 cuft/ja
Diameter = 9 in
Kecepatan putaran = 40 rpm

Spesifikasi :

Fungsi = Untuk mendinginkan kristal dan membawa ke bucket elevator
Type = Plain sponts or chutes
Kapasitas = 272,8492 cuft/jam
Panjang = 30 ft
Diameter = 9 in
Kecepatan putaran = 40 rpm
power = 2 hp
Jumlah = 1 buah

35. BUCKET ELEVATOR (J-356)





Fungsi : Untuk mengangkut kristal dari belt conveyor ke hopper
Type : Centrifugal discharge elevator
Bahan : Carbon Steel
Perhitungan :
Rate massa = 12710,8519 kg/jam
= 28022,59841 lb/jam
ρ bahan = 81,7925 lb/cuft
Data dari (Perry : 21-8)
Tinggi bucket = 25 ft
Putaran poros = 43 rpm

Untuk kapasitas maksimum = 14 ton/jam Kecepatan buket elevator sebesar 225 ft/menit

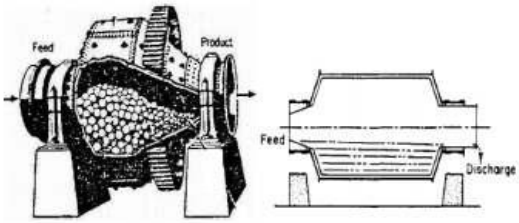
Sehingga untuk kapasitas = 12,7109 ton/jam
maka,

Kecepatan bucket elevator = $\frac{12,7109}{14}$ x 225
= 204,2815 ft/menit
Power pada head shaft = 1,6 hp
Power tambahan = 2% hp tiap ft
= 0,02 hp/ft x 25 ft
= 0,5 hp
P total = 1,6 + 0,5
= 2,1
Ukuran Bucket = 6" x 4" x 4,25"
Bucket spacing = 12 in
Efisiensi motor = 80% (Hasse, 1962)
Maka motor penggerak yang digunakan = $\frac{2,1}{0,8}$
= 2,625 hp

Spesifikasi :
Fungsi : Untuk mengangkut produk ke ball mill
Type : Continous discharge bucket elevator
Dasar pemilihan : Dapat memindahkan bahan dengan ketinggian tertentu
Kapasitas : 12,7109 ton/jam
Tinggi Bucket : 25 ft
Kecepatan Bucket : 204,2815 ft/menit
Bucket Spasing : 12 in
Ukuran Bucket : 6" x 4" x 4,25"
Putaran head shaft : 43 rpm
Lebar belt : 7 in

Power : 2,625 hp
Jumlah : 1 buah

36. BALL MILL (C-360)



Fungsi : Menghaluskan solid sampao 200 mesh
Type : Mercy Ball Mill Grinding System, Air-Lift Type
Dasar pemilihan : Tekanan oprasi = 1 atm
Suhu oprasi = suhu kamar
Waktu oprasi = continue

Pergitungan :
Rate bahan = 12710,85194 kg/jam
= 28022,59841 lb/jam
= 12,71085194 ton/jam
= 305,0604467 ton/hari

Berdasarkan rate massa dalam ton/hari, didaptkan spesifikasi (Perry, 2008) untuk produk berukuran 200 mesh dengan kapasitas = 305,0604 ton/hari
diperoleh : Jenis ball mill = Mercy Ball Mill
Power = 345-380 hp ,maka dipilih 360 hp
No. Sleve = 200 mesh
Diameter = 6 ft
Panjang = 4 1/2 ft
Rate maksimum = 315 ton/jam
Mill speed = 24 rpm
Berat bola baja = 8,9 ton

Direncanakan Ukuran Ball Mill :
Panjang Mill = 7 ft
Diameter Mill = 5 ft
Tinggi Mill = 5 ft

Untuk Marcy ball mill, maka digunakan 3 ukuran bola baja :
5 & 3,5 & 2,5 in **(Stanley 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 : $\frac{8,90}{3}$ = 2,97 ton
Perhitungan jumlah ball :
Diameter bola baja 5 in = 0,127 m

Jarir-jari bola baja = 0,127 / 2 = 0,0635 m

Volume bola = (4/3) π R³ = 0,0010720 m³ = 1,0720 L

densitas bola (steel) = 4,8 gram/cm **(Perry ed.7 20-33)**

= 4,8 kg/L

Berat(massa) Bola = 4,8 kg/L x 1,0720 L

= 5,146 kg

Berat total untuk baja ukuran 5 in = 2,97 ton

= 2966,7 kg

Jumlah baja ukuran 5 in = 2966,7 / 5,146

= 576,551 Buah

Diameter bola baja 3,5 in = 0,0889 m

Jarir-jari bola baja = 0,0889 / 2 = 0,04445 m

Volume bola = (4/3) π R³ = 0,0003677 m³ = 0,3677 L

densitas bola (steel) = 4,8 gram/cm **(Perry ed.7 20-33)**

= 4,8 kg/L

Berat(massa) Bola = 4,8 kg/L x 0,3677 L

= 1,765 kg

Berat total untuk baja ukuran 4 in = 2,97 ton

= 2966,7 kg

Jumlah baja ukuran 3,5 in = 2966,7 / 1,765

= 1680,908 Buah

Diameter bola baja 2,5 in = 0,0635 m

Jarir-jari bola baja = 0,0635 / 2 = 0 m

Volume bola = (4/3) π R³ = 0,0001340 m³ = 0,1340 L

densitas bola (steel) = 4,8 gram/cm **(Perry ed.7 20-33)**

= 4,8 kg/L

Berat(massa) Bola = 4,8 kg/L x 0,1340 L

= 0,643 kg

Berat total untuk baja ukuran 3 in = 2,97 ton

= 2966,7 kg

Jumlah baja ukuran 2,5 in = 2966,7

$$= \frac{}{0,643}$$

= 4612,410 Buah

Perhitungan kecepatan kritis :

Nc = $76,6 / D^{0,5}$ **(Perry 7ed : 20-32)**

dimana : Nc = Kecepatan kritis ; rpm

D = Diameter mill ; ft

$$Nc = \frac{76,6}{D^{0,5}}$$

$$= \frac{76,6}{5^{0,5}}$$

= 34,3 rpm

Kecepatan actual = 60 - 80% dari kecepatan kritis **(Perry 7ed : 20-32)**

ditetapkan : N = 75% Nc

= 75% x 34,3

= 26 rpm

Ditetapkan kecepatan actualnya = 26 rpm

Perhitungan power yang dibutuhkan :

Spesifikasi :

Fungs : Menghaluskan solid sampao 200 mesh

Type : Marcy Ball Mill

Dasar Pemilihan : Sesuai dengan jenis Bahan dan kapasita

Kapasitas : 305,0604467 hp ton/hari

Rate maksimum : 315 ton/hari

Diameter mill : 5 ft

Panjang mill : 7 ft

Kecepatan putaran a : 26 rpm

Power : 360 hp

Bahan ball : stainless steel

Bahan konstruksi : stainless steel A193 grade B8,

Bola Ball Charge : 8,90 ton

Ukuran bola baja : 5 & 3,5 & 2,5 in

Jumlah bola : 5 in = 577 buah

3,5 in = 1681 buah

2,50 in = 4612 buah

Jumlah : 1 buah

37. SCREW CONVEYOR (J-361)

Fungsi : Untuk mengangkut kristal ke Bucket Elavator

Type : Plain sponts or chutes

Dasar Pemilihan : Umum digunakan untuk padatan dengan sistem tertutup

Bahan masuk

Komponen	Berat	Fraksi	ρ (gr/cm^3)
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12626,263	0,9933	1,65
$Al_2(SO_4)_3$	5,021001129	0,0004	2,67
$(NH_4)_2SO_4$	16,62536142	0,0013	1,77
H_2SO_4	62,92812488	0,005	1,97
H_2O	0,01445732	1E-06	1
Total	12710,852	1	

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

1 gr/cc = 62,43 lb/cuft

$$\rho \text{ campuran} = \frac{1}{\frac{0{,}9933}{1{,}65} + \frac{0{,}0004}{2{,}7} + \frac{0{,}0013}{1{,}77} + \frac{5\text{,E-}03}{1{,}97} + \frac{}{0{,}000001137}} \times 62{,}43$$

$$= \frac{1}{} = 103{,}1171 \text{ lb/cuft}$$

Data perhitungan :

Rate bahan = 12710,852 kg/jam
= 28022,598 lb/jam

ρ campuran = 103,1171 lb/cuft
= 1,6519 gr/ml

$$\text{Rate volumetrik} = \frac{\text{rate massa}}{\rho \text{ campuran}} \times \text{waktu tinggal}$$

$$= \frac{28022{,}598 \text{ lb/jam}}{103{,}1171 \text{ lb/cuft}}$$

= 271,7552285 cuft/jam
= 4,5293 cuft/menit
= 33,8812 gpm

dari (Badger, 1955), bahan termasuk kelas D dengan F = 2,5

Power motor = $\frac{CLWF}{33000}$ (Badger: 360)

Dengan :
C = Kapasitas (cuft/menit)

L = Panjnag (ft)
W = Densitas bahan (lb/cuft)
F = Faktor bahan

Direncanakan panjang screw conveyor = 30 ft

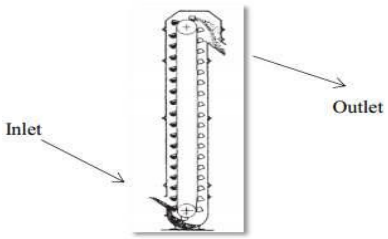
$$\text{Power} = \frac{(\ 4{,}5293 \times 30 \times 103{,}117 \times 2{,}5\ )}{33000}$$

= 1,06146 hp

Karena power < dari 2 hp, maka :
Power = 2 x 1,06146
= 2,1229 ≈ 2 hp
Dari (Perry : Tabel 21-6) dipilih screw conveyor :
Kapasitas = 271,7552 cuft/jam
Diameter = 9 in
Kecepatan putaran = 40 rpm

Spesifikasi :
Fungsi = Untuk mengangkut Produk menuju ke silo
Type = Plain sponts or chutes
Kapasitas = 271,7552 cuft/jam
Panjang = 30 ft
Diameter = 9 in
Kecepatan putaran = 40 rpm
power = 2 hp
Jumlah = 1 buah

38. BUCKET ELEVATOR (J-362)



Fungsi : Untuk mengangkut amonium sulfat dari belt conveyor ke hopper
Type : Centrifugal discharge elevator
Bahan : Carbon Steel
Perhitungan :
Rate massa = 12710,85 kg/jam
= 28022,59841 lb/jam
ρ bahan = 81,7925 lb/cuft
Data dari (Perry, 2008)

Tinggi bucket = 8 ft
Putaran poros = 43 rpm

Untuk kapasitas maksimum = 14 ton/jam Kecepatan buket elevator sebesar 225 ft/menit

Sehingga untuk kapasitas = 12,7109 ton/jam
maka,

Kecepatan bucket elevator = $\frac{12,7109}{14}$ x 225
= 204,2815 ft/menit

Power pada head shaft = 1,6 hp
Power tambahan = 2% hp tiap ft
= 2% hp/ft x 8 ft
= 0,2 hp
P total = 1,6 + 0,16
= 1,8
Ukuran Bucket = 6" x 4" x 4,25"
Bucket spacing = 12 in
Efisiensi motor = 80% (Hasse, 1962)
Maka motor penggerak yang digunakan = $\frac{1,76}{0,8}$
= 2,2 hp

Spesifikasi :

Fungsi : Untuk mengangkut produk ke silo
Type : Continous discharge bucket elevator
Dasar pemilihan : Dapat memindahkan bahan dengan ketinggian tertentu
Kapasitas : 12,7109 ton/jam
Tinggi Bucket : 8 ft
Kecepatan Bucket : 204,2815 ft/menit
Bucket Spasing : 12 in
Ukuran Bucket : 6" x 4" x 4,25"
Putaran head shaft : 43 rpm
Lebar belt : 7 in
Power : 2,2 hp
Jumlah : 1 buah

39. SILO (F-370)

Fungsi : Mengangkut produk ke packing
Type : Silinder dengan tutup bawah berbentuk konical dengan posisi vertikal

Bahan masuk

Komponen	Berat	Fraksi berat	ρ (gr/cm^3)
$Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$	12626,263	0,99334514	1,65
$Al_2(SO_4)_3$	5,021001129	4,E-04	2,67
$(NH_4)_2SO_4$	16,62536142	1,E-03	1,77
H_2SO_4	62,92812488	5,E-03	1,97
H_2O	0,01445732	0,0000	1
Total	12710,852	1	

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

1 gr/cc = 62,43 lb/cuft

$$\text{ampuran} = \frac{1}{\frac{0{,}9933}{1{,}65} + \frac{0{,}0004}{2{,}7} + \frac{1{,}E\text{-}03}{1{,}77} + \frac{5{,}E\text{-}03}{1{,}97} + \frac{0{,}0000}{1}} \times 62{,}43$$

$$= 103{,}1171 \text{ lb/cuft}$$

Data perhitungan :

Rate bahan = 12710,852 kg/jam
= 28022,598 lb/jam
ρ campuran = 103,1171 lb/cuft
Waktu tinggal = 12 jam

$$\text{Rate volumetrik} = \frac{\text{rate massa}}{\rho \text{ campuran}} \times \text{waktu tinggal}$$

$$= \frac{28022{,}598 \text{ lb/jam}}{103{,}1171 \text{ lb/cuft}} \times 12 \text{ jam}$$

$$= 3261{,}062741 \text{ cuft}$$

Asumsi volume bahan m 80% volume tangki

$$\text{Volume tangki} = \frac{3261{,}062741}{0{,}8}$$

$$= 4076{,}328427 \text{ cuft}$$

Penentuan dimensi silo :

Ditentukan :

α = Sudut conis : 60 ^{o}

D = Diameter tangki : ft

m = Flat spot center : 12 in = 1 ft

Asumsi : H = 1.5 D

Volume tangki = $1/4\ \pi D^2 H$

$4076{,}328427 = \frac{1}{4}\ 3{,}14\ D^2\ 1{,}5\ D$

$D^3 = 3461{,}850044$

D = 15,128 ft = 181,5309428 in

H = 1.5 D maka,

H = 22,6914 ft = 272,2964142 in

Tinggi feed dalam tangki :

Volume feed = $1/4\ \pi D^2 H$

$3261{,}062741 = \frac{1}{4} \times 3{,}14 \times 228{,}84 \times H$

H = 18,1531 ft = 217,837 in

Sudut yang diambil α = 60

$H = \frac{tg\alpha \times (D - m)}{2}$ (Hasse, 1962)

$= \frac{tg\ 60\ (\ 15{,}128\ -\ 1\ )}{2}$

= 2,2607

Volume conical = $0{,}262\ h\ (D^2 + Dm + m^2)$

= 0,3 x 2,3 x 244,97

= 145,0971452 cuft

Volume shell = 4076,328427 - 145,097145

= 3931,231282 cuft

Tinggi total = 22,6914 + 2,2607

= 24,952 ft

= 299,425 in

Penentuan tebal shell dan conical

Bahan kontruksi dipilih Carbon Steel SA-283 grac (Brownel, 1959)

$f_{allowable}$ = 12650 (Tabel 13.1)

C = 1/8 in

Sambungan las dengan type double welded butt joint

Efisiensi las, E = 0,8

tekanan desaign = 1 atm = 14,7 psi

r = 1/2 x D

= 1/2 x 181,5

= 90,7655 in

Tekanan bahan = $\frac{\mu H}{144}$

= $\frac{103,12 \quad 24,952}{144}$

= 17,8679 psig

Tekanan oprasi = 14,7 psi

Faktor keamanan 10%

P_{design} = 1,1 $P_{perencanaan}$

= 35,8247 psig

Rumus tebal shell :

$t_{min} = \frac{P \times ri}{fe - 0,6P} + C$ (Brownell & Young, 1959)

$= \frac{(\quad 35,825 \quad \times \quad 90,76547142 \quad)}{((\quad 12650 \quad \times \quad 0,8) - (\quad 0,6 \quad \times \quad 35,825))} + \quad 0,125$

= 0,4470 in

Diambil tebal shell = 0,5 in

Penentuan tebal bagian bawah :

Jenis : Conical

Type : Singel welded butt joint tanpa backing up strip dengan effisiensi 80%

$t_{min} = \frac{P \times r}{2 \cos \alpha (fe - 0,6P)} + C$

$= \frac{(\quad 35,8 \quad \times \quad 91 \quad)}{2 \cos 45 \quad ((\quad 12650 \quad 0,8) - (\quad 0,6 \quad \times \quad 35,825))} + \quad 0,125$

= 0,4314 in

= 1/2 in

Spesifikasi :

Fungsi	=	Menampung produk sementara
Type	=	Silinder dengan tutup bawah berbentuk conis dengan posisi verikal
Kapasitas	=	4076,328427 cuft
Diameter silinder	=	24,952 ft
Tinggi silinder	=	22,6914 ft
tebal shell	=	1/2 in
Tinggi conical	=	2,2607 ft
Cone angle	=	60 ^{o}
Tebal angle	=	1/2 in
Jumlah	=	1 buah

APENDIX D
PERHITUNGAN ANALISA EKONOMI

Kapasitas Produksi	=	100.000	Ton/tahun
	=	12.626,2626	Kg/jam
Bahan Baku			
Aluminium Sulfat	=	6908,6301	kg aluminium sulfat
Ammonium Sulfat	=	2677,5493	kg/jam ammonium sulfat

1. Harga Peralatan

Tabel 1. Indeks Harga Peralatan

Tahun	Index Harga
2011	191,2
2012	194,6
2013	201,2
2014	204,9
2015	206,2
2016	207,3
2017	213,6
2018	222,9
2019	232,2
2020	239,1
2021	257,5

Chemical engineering cost design

Dengan metode least square dan data-data pada tabel di atas dilakukan pendekatan atau penafsiran indeks harga peralatan pada awal tahun dimana data-data

keterangan :

Y = indeks harga peralatan pada tahun ke-n

X = tahun ke-n

No	X	Y	X^2	Y^2	XY
1	2011	191,2	4044121	36557,44	384503,2
2	2012	194,6	4048144	37869,16	391535,2
3	2013	201,2	4052169	40481,44	405015,6
4	2014	204,9	4056196	41984,01	412668,6
5	2015	206,2	4060225	42518,44	415493
6	2016	207,3	4064256	42973,29	417916,8
7	2017	213,6	4068289	45624,96	430831,2
8	2018	222,9	4072324	49684,41	449812,2
9	2019	232,2	4076361	53916,84	468811,8

10	2020	239,1	4080400	57168,81	482982
11	2021	257,5	4084441	66306,25	520407,5
Jumlah	22176	2370,7	44706926	515085,05	4779977,1

Jumlah data (n) = 11

Pers 17-21, Peters & Timmerhauss

$$\sum\left(\bar{x}-x\right)^2=\sum x^2-\frac{\left(\sum x\right)^2}{n} \quad = \quad 110$$

$$\sum\left(\bar{y}-y\right)^2=\sum y^2-\frac{\left(\sum y\right)^2}{n} \quad = \quad 4156{,}096$$

Pers 17-20, Peters & Timmerhauss

$$\sum\left(\bar{x}-x\right)\left(\bar{y}-y\right)=\sum xy-\frac{\sum x\sum y}{n} \quad = \quad 646$$

$$b=\frac{\sum\left(\bar{x}-x\right)\left(\bar{y}-y\right)}{\sum\left(\bar{x}-x\right)^2} \quad = \quad 5{,}87$$

ıta-rata y = $\frac{\text{Jumlah Y}}{\text{n}}$ = a = 215,5182

ıta-rata x = $\frac{\text{Jumlah X}}{\text{n}}$ = c = 2016

y = a + b (x-c)
= 215,51818 + 5,87 (x - 2016)
= 215,51818 + 5,87 x -11837,5855
= -11622,0673 + 5,87 x

Asumsi pabrik berdiri pada tahun 2024 maka
Dari persamaan di atas diperoleh indeks harga pada tahun 2024 sebesar
y = 262,4927

:p, V, S = Cp, V, r (Is/Ir)

Keterangan : Cp, V, S harga peralatan pada tahun dan kapasitas V

Is : Cost indeks pada tahun 2024
Ir : Cost Indeks pada tahun data
Harga pada bulan januari tahun 2024 (Ir)

Kurs Dollar pada tahun 2022
(US $) 1 = 1$ = Rp 14.355

Contoh perhitungan harga peralatan
Pompa
Jenis : Centrifugal pump

Dari Alibaba harga alat pada tahun 2022 sebesar :

Harga Pompa = $ 460 (www.Alibaba.com)
Indeks harga tahun 2021 = 257,50
Indeks harga tahun 2024 = 262,49

$$\text{Harga alat pada tahun 2024} = \frac{\text{Index Tahun 2024}}{\text{Index tahun 2021}} \times \text{Harga Alat tahun 2021}$$

$$\text{Harga alat pada tahun 2024} = \frac{262,49}{257,50} \times \$\ 460,00$$

= $ 468,92
= $ 468,92 x Rp 14.355
= Rp 6.731.332,92

Tabel 2 Perhitungan Harga Peralatan Proses

No	Nama Alat	Kode	Harga per unit (USS)		Jmlh	Harga Total
			2021	2024		US $
1	Gudang aluminium sulfat	F-110	5.000	5.097	1	5.097
2	Belt conveyer	J-111	1.800	1.835	1	1.835
3	Bucket elevator	J-112	3.907	3.983	1	3.983
4	hopper aluminium sulfat	F-113	800	816	1	816
5	Tangki pelrut aluminium sulfat	M-120	10.000	10.194	1	10.194
6	Pompa 1	L-121	460	469	1	469
7	Clarifier	H-122	15.000	15.291	1	15.291
8	Tangki penampung	F-123	2.000	2.039	1	2.039
9	Pompa 2	L-124	460	469	1	469
10	Heater 1	E-125	10.000	10.194	1	10.194
11	Gudang ammonium sulfat	F-130	5.000	5.097	1	5.097
12	Belt conveyer	J-131	1.800	1.835	1	1.835
13	Bucket elevator	J-132	3.907	3.983	1	3.983
14	Hopper ammonium sulfat	F-133	800	816	1	816
15	Tangki pelarut ammonium sulfat	M-140	10.000	10.194	1	10.194
16	Pompa 3	L-141	460	469	1	469
17	Heater 2	E-142	10.000	10.194	1	10.194
18	Reaktor	R-210	30.000	30.582	1	30.582
19	Pompa 4	L-211	460	469	1	469
20	Tangki Penampung Sementara	F-220	3.000	3.376	2	6.752
21	Pompa 5	L-221	460	469	1	469

22	Evaporator	V-320	25.000	25.485	1	25.485
23	Kondensor	E-321	8.000	8.155	1	8.155
24	Pompa 6	L-322	460	469	1	469
25	Kristalizer	X-330	15.000	15.291	2	30.582
26	Centrifuge	H-340	15.000	15.291	1	15.291
27	Bak Penampung Mother Liquor	F-341	2.000	2.038,78	1	2.038,78
28	Screw Conveyer 1	J-342	3.500	3.568	1	3.568
29	Rotary Dryer	B-350	40.000	40.776	1	40.776
30	Blower	E-351	2.000	2.039	1	2.039
31	Molecular Sieve Tray	D-352	10.000	10.045	1	10.045
32	Heater 3	E-352	10.000	10.194	1	10.194
33	Cyclone	H-353	5.500	5.607	1	5.607
34	Cooling conveyer	J-354	3.500	3.568	1	3.568
35	Bucket elevator 3	J-355	3.907	3.983	1	3.983
36	Ball Mill	C-360	19.000	19.368	1	19.368
37	Bucket elevator 4	J-361	3.907	3.983	1	3.983
38	Belt Conveyer 3	J-362	3.500	3.568	1	3.568
39	Silo aluminium amonium sulfat	F-370	8.000	8.155	1	8.155
Total						308.071

Tabel 3 Harga Peralatan Utilitas

No	Nama Alat	Kode	Harga per unit (USS)		Jmlh	Harga Total
			2021	2024		US $
1	Boiler		30.000	30.582	1	30.582
2	Cooling Tower	P-350	10.000	10.194	1	10.194
3	Pompa air sungai	L-111	3.000	3.058	1	3.058
4	Bak penampung air sungai	F-110	10.000	10.194	1	10.194
5	Pompa koagulasi	L-112	2.500	2.548	1	2.548
6	Bak koagulasi	M-210	10.000	10.194	1	10.194
7	Bak flokulasi	M-220	10.000	10.194	1	10.194
8	Clarifier	H-310	20.000	20.388	1	20.388
9	Bak penampung endapan	F-311	4.000	4.078	1	4.078
10	Bak penampung air jernih	F-312	8.000	8.155	1	8.155
11	Kation exchanger	H-330	2.650	2.701	1	2.701
12	Pompa Bak Air pendingin	F-326	2.000	2.039	1	2.039
13	Pompa Sand Filter	L-313	2.000	2.039	1	2.039
14	Sand filter	H-320	5.000	5.097	2	10.194
14	Bak penampung air bersih	F-321	8.000	8.155	1	8.155
15	Pompa air kation exchanger	L-323	1.000	1.019	1	1.019
16	Pompa Bak Air pendingin	L-324	2.000	2.039	1	2.039
17	Pompa air anion exchanger	L-331	1.000	1.019	1	1.019
18	Pompa Bak Sanitasi	L-322	2.000	2.039	1	2.039

18	Anion exchanger	H-340	10.000	10.194	4	40.776
19	Bak penampung air boiler	F-344	3.000	3.058	1	3.058
20	Pompa bak air sanitasi	L-322	350	357	1	357
21	Bak penampung air sanitasi	F-325	2.000	2.039	1	2.039
22	Pompa air pendingin	L-351	2.000	2.039	1	2.039
23	Bak penampung air pendingin	F-326	2.500	2.548	1	2.548
24	Pompa air proses	L-342	350	357	1	357
25	Bak penampung air proses	F-345	1.500	1.529	1	1.529
26	Generator set		50.000	50.969	2	101.939
27	Tangki penyimpan bahan bakar		18.000	18.349	2	36.698
Total						332.169

Total Harga Peralatan = Peralatan Proses + Peralatan Utilitas
= $ 308.071,00 + $ 332.168,65
= $ 640.239,65 x Rp 14.355
= Rp 9.190.640.117

2. Harga Bahan Baku

a. Aluminium Sulfat
Jumlah Kebutuhan = 6908,6301 kg aluminium sulfat
Harga aluminium sulfat = Rp 2.250 /kg (Alibaba,2022)
Biaya per Tahun = 6908,6301 x 24 x 330 x 2.250
= Rp123.111.789.224

b. Ammonium Sulfat
Jumlah Kebutuhan = 2677,5493 kg/jam ammonium sulfat
Harga ammonium sulfat = Rp 1.431 kg (Alibaba,2022)
Biaya per Tahun = 2677,5493 x 24 x 330 x 1431
= Rp 30.346.058.737

3. Harga Jual Produk

Produk Utama

Aluminium Ammonium Sulfat
Jumlah Produk = 100.000 Ton/tahun
Harga Produk = 5650 /kg (Alibaba Indonesia, 2022)
Harga Jual Produk = 100.000.000 x 5650
= Rp565.000.000.000

4. Biaya Pengemasan Produk

Jumlah Produk = 100.000 Ton/tahun
= 100.000.000 Kg/tahun
(Produk dikemas dalam bag 50 kg)
Kebutuhan Bag = 2.000.000 /tahun

Harga 1 Bag	=	Rp	5.000
Biaya pengemasan per tahun	=	£	10.000.000.000
Biaya pendukung (10% pengemasan)	=	Rp	1.000.000.000
Total Biaya Pengemasan Per Tahun	=	Rp	11.000.000.000

Total biaya penjualan = Total harga jual produk + Biaya pengemasan
= Rp576.000.000.000

5. Tabel Gaji Karyawan

Tabel 4 Gaji Pokok

No	Jabatan	Gaji/bulan	Jmlh	Gaji/Tahun
1	Direktur Utama	Rp 40.000.000	1	Rp 480.000.000
2	General manajer	Rp 25.000.000	1	Rp 300.000.000
3	Manajer :			
	Manajer Keuangan	Rp 20.000.000	1	Rp 240.000.000
	Manajer Produksi	Rp 20.000.000	1	Rp 240.000.000
	Manajer Pemasaran	Rp 20.000.000	1	Rp 240.000.000
	Manajer Personalia	Rp 20.000.000	1	Rp 240.000.000
4	Staff Ahli	Rp 12.000.000	3	Rp 432.000.000
5	Kepala Bagian :			
	Produksi	Rp 10.000.000	1	Rp 120.000.000
	Teknik	Rp 10.000.000	1	Rp 120.000.000
	Keuangan	Rp 10.000.000	1	Rp 120.000.000
	Pemasaran	Rp 10.000.000	1	Rp 120.000.000
	Umum	Rp 10.000.000	1	Rp 120.000.000
6	Kepala Seksi :			
	Proses	Rp 8.000.000	1	Rp 96.000.000
	Utilitas	Rp 8.000.000	1	Rp 96.000.000
	Laboratorium	Rp 8.000.000	1	Rp 96.000.000
	Pengendalian proses	Rp 8.000.000	1	Rp 96.000.000
	Pemiliharaan	Rp 8.000.000	1	Rp 96.000.000
	Health and Safety	Rp 8.000.000	1	Rp 96.000.000
	Pembelian	Rp 6.000.000	1	Rp 72.000.000
	Pemasaran	Rp 6.000.000	1	Rp 72.000.000
	Keuangan	Rp 6.000.000	1	Rp 72.000.000
	Administrasi	Rp 6.000.000	1	Rp 72.000.000
	Personalia	Rp 6.000.000	1	Rp 72.000.000
	Keamanan	Rp 6.000.000	1	Rp 72.000.000
7	Sekretaris	Rp 6.000.000	1	Rp 72.000.000
8	Staf Seksi :			
	Laboratorium	Rp 5.000.000	12	Rp 720.000.000
	Pemeliharaan	Rp 5.000.000	3	Rp 180.000.000

	Health and Safety	Rp 4.500.000	6	Rp	324.000.000
	Pembelian	Rp 4.500.000	6	Rp	324.000.000
	Pemasaran	Rp 4.500.000	6	Rp	324.000.000
	Keuangan	Rp 4.500.000	6	Rp	324.000.000
	Administrasi	Rp 4.500.000	6	Rp	324.000.000
	Personalia	Rp 4.500.000	6	Rp	324.000.000
	Keamanan	Rp 4.500.000	6	Rp	324.000.000
9	Karyawan / Staf Proses shift	Rp 5.000.000	85	Rp	5.100.000.000
11	Karyawan / Staf Proses Utilita	Rp 5.000.000	25	Rp	1.500.000.000
12	Dokter	Rp 10.000.000	3	Rp	360.000.000
12	Paramedis	Rp 5.000.000	3	Rp	180.000.000
13	Satpam	Rp 4.300.000	30	Rp	1.548.000.000
14	Sopir	Rp 4.300.000	20	Rp	154.800.000
15	Cleaning service	Rp 4.300.000	20	Rp	516.000.000
Total		Rp375.500.000	270	**Rp**	**15.924.000.000**

Tunjangan karyawan diberikan setiap 1 kali setiap tahun

Maka total gaji karyawan = Gaji Total 1 Tahun + Gaji Total 1 Bulan

= Rp15.924.000.000 + Rp375.500.000

= Rp16.299.500.000

6. Kebutuhan Utilitas

a. Air

Kebutuhan air tiap hari = 13566,2521 m^3/hari

Biaya air tiap hari = 13566,25 x Rp 2.200

= Rp 29.845.754,65

Biaya pengolahan per tahun = Rp 9.849.099.035

b. Kebutuhan penunjang pengolahan air

1. Kebutuhan $Al_2(SO_4)_3$ = 106370,27 kg/tahun

Harga $Al_2(SO_4)_3$ = Rp 4.500 per kg

Biaya tawas per tahun = Rp 478.666.213

2. Kebutuhan PAC

Kebutuhan PAC tiap tahun = 15957 kg/tahun

Biaya PAC per kg = Rp 12.500 per kg

Biaya PAC tiap tahun = Rp 199.460.211

3. Kebutuhan Dowex Kation = 454365,8751 m^3/tahun

= 454365875,068 L/tahun

Harga Dowex = Rp 36.000 per 1L

Biaya dowex per tahun = Rp 16.357.171.502

4.	Kebutuhan HCl 33%	=	83109,88	liter/tahun	
	Harga HCl	=	Rp 15.000	per liter	
	Biaya HCl per tahun	=	83109,88 x	Rp	15.000
		=	Rp	1.246.648.163	
5.	Kebutuhan dowex anion	=	302910,5834	L/tahun	
	Harga Dowex anion	=	Rp 36.000	per 1L	
	Biaya Dowex anion per tahun	=	302911 x	Rp	36.000
		=	Rp		10.904.781.002
6.	Kebutuhan NaOH	=	46522,1	kg/tahun	
	Harga NaOH	=	Rp 12.500	per kg	
	Biaya NaOH per tahun	=	46522,1 x	Rp	12.500
		=	Rp		581.526.291
7.	Bahan Bakar				
	Kebutuhan bahan bakar tiap hari	=	87304	L/hari	
	Biaya bahan bakar per liter	=	Rp 6.500		
	Biaya bahan bakar tiap tahun	=			187.267.463.785,83
8.	Listrik				
	Kebutuhan listrik tiap hari	=	3494,88	kWh	
	Biaya listrik per kWh	=	Rp995		
	Biaya listrik tiap tahun	=	Rp		1.147.542.670

Jadi total Biaya Utilitas pertahun = Rp 228.032.358.873

7. Perhitungan Tanah dan Bangunan

Luas Tanah	=	20000	m^2	
Harga tanah/m2	=	Rp 5.000.000		
Total harga tanah	=	Rp		100.000.000.000
Luas bangunan pabrik	=	20000	m2	
Harga bangunan pabrik per m2	=	Rp 4.000.000		
Harga bangunan pabrik total	=	Rp		80.000.000.000
Luas bangunan gedung	=	5450	m2	
Harga bangunan gedung	=	Rp		3.500.000
Harga bangunan gedung total	=	Rp		19.075.000.000
Harga bangunan total	=	Rp		99.075.000.000

Total harga tanah dan bangunan	=	Rp	177.275.000.000