BAB IX

KESIMPULAN

Pabrik dinatrium fosfat heptahidrat secara kontinyu dengan kapasitas 30.000 ton/tahun setelah dilakukan perancangan awal, baik dari segi teknik maupun segi ekonomi, dapat disimpulkan bahwa pabrik ini memiliki resiko yang sedang serta layak dan menarik untuk didirikan, karena memiliki indikator perekonomian yang relatif baik yaitu:

Tabel 25. Analisis kelayakan ekonomi

No	Analisis kelayakan	Kriteria	Hasil Perhitungan
1	Laba sebelum pajak Laba sesudah pajak		Rp 133.805.681.395 Rp 93.663.976.977
2	ROI sebelum pajak ROI sesudah pajak	Minimum 11%	48,468 % 33,928 %
3	POT sebelum pajak POT sesudah pajak	Maksimum 5 tahun	2,276 tahun 1,7103 tahun
4	BEP	40%-60%	41,071 %
5	SDP		25,543 %
6	DCF	1,5-2 kali bunga bank	7.612 %

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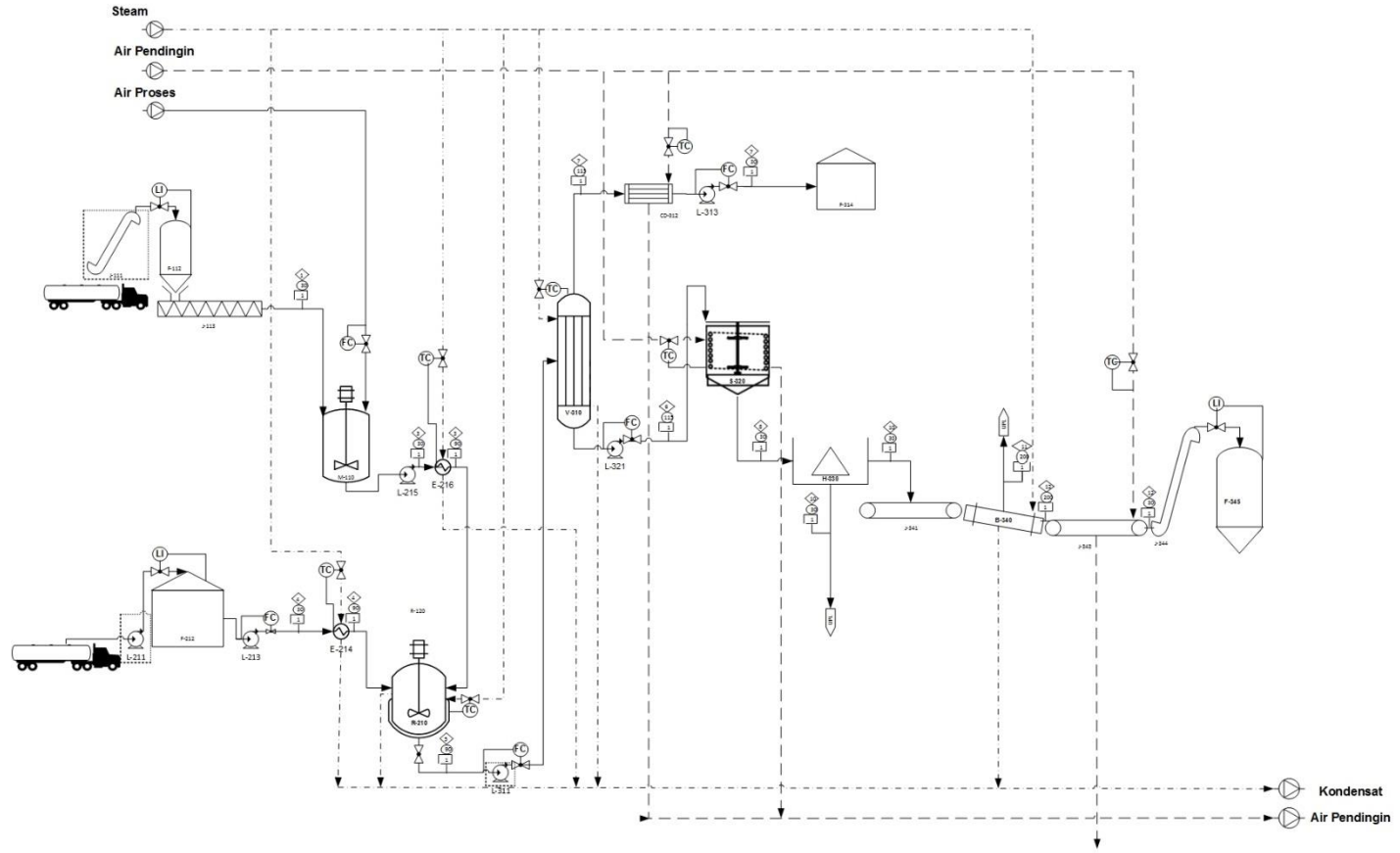

Kode	Nama Alat
J-111	Bucket Elevator-1
F-112	Silo NaCl
J-113	Screw Conveyor
M-110	Mixer
L-211	Pompa-1
F-212	Tangki H3PO4
L-213	Pompa-2
E-214	Heater-1
R-210	Reaktor
L-215	Pompa-3
E-216	Heater-2
L-311	Pompa-4
V-310	Evaporator
CD-312	Kondensor
L-313	Pompa-5
F-314	Tangki HCl
L-321	Pompa-6
B-320	Kristaliser
H-330	Centrifuge
J-341	Belt Conveyor
B-340	Rotary Dryer
J-343	Cooling Conveyor
J-344	Bucket Elevator-3
F-346	Silo Produk

KODE	KETERANGAN
LI	LEVEL INDICATOR
TC	TEMPERATURE CONTROL
FC	FLOW CONTROL
○	NOMOR ARUS
◇	TEKANAN (atm)
□	TEMPERATURE (°C)
- · - · -	STEAM
— — —	AIR PENDINGIN
———	AIR PROSES

No.	NOMOR ARUS / KOMPONEN	SATUAN (KG/JAM)											
		1	2	3	4	5	6	7	8	9	10	11	12
1.	NaCl	3726		3277		163,8321	163,8321		163,8321	149,0871	15	15	
2.	H3PO4				2747	137,3443	137,3443		137,3443	137,3443	12,36	12,36	
3.	H2O	33,1	7612	7645,5	430,0236	8075,5216	2508,343	5567,1786	2282,6	2282,6	225,75	225,75	
4.	Na2HPO4					3789,5862	3780,586		60,88	60,88	6	6	
5.	Na2HPO4.7H2O										3713,607		3713,6067
6.	HCl					1941,765		1941,765					
TOTAL		3759,1	7612	10922,5	3177,024	12166,284	6590,105	7508,94	2629,9	2619,9	3972,717	259,11	3713,606

DIAGRAM ALIR PROSES PRARANCANGAN PABRIK NATRIUM DIFOSFAT HEPTAHIDRAT DARI NATRIUM KLORIDA DAN ASAM FOSFAT
KAPASITAS 30.000 TON / TAHUN

PROGRAM STUDI S1 TEKNIK KIMIA
FAKULTAS TEKNIK
UNIVERSITAS SETIA BUDI SURAKARTA
2019

Oleh :
Esther Mutiara Santallum Ekklesia Tibalia
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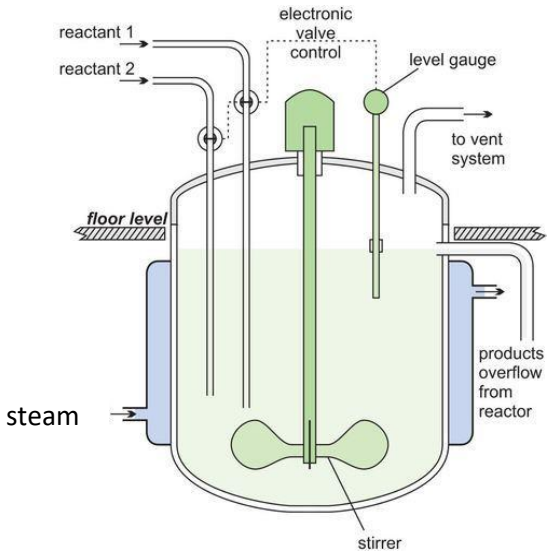
2. Gregorius Prima Indra Budianto, S. T., M.Eng.

LAMPIRAN A

REAKTOR



Komponen	Fw (kg/jam)	Fraksi	kmol	pi (kg/L)	Fv (L/jam)	Fraksi pi
NaCl	163,8320999	0,01347604	2,8029444	2,163	75,742996	0,029148684
H3PO4	137,3442753	0,01129728	1,4014722	1,834	74,887827	0,020719216
H2O	8075,521571	0,66425375	448,39098	0,997	8099,821	0,66226099
Na2HPO4	3780,586151	0,31097292	26,631348	0,5	7561,1723	0,155486461
Total	12157,2841	1			15811,624	0,867615351

Densitas campuran = 0,867615351 kg/L

Volumetric flow (Fv) = 15811,624 L/jam

	2NaCl	H3PO4	→	Na2HPO4	2HCl
m	51,32591959	25,6629598			
r	48,76	24,38		24,379812	48,76
s	2,566295979	1,28314799		24,379812	48,75962361

Cbo NaCl = 0,00324609 kmol/L

Cao H3PO4 = 0,00162304 kmol/L

Cb NaCl = 0,001704196 kmol/L

Ca H3PO4 = 8,11522E-05 kmol/L

Diketahui (*Jurnal Research and Design Trans IchemE Part A, 2007)*

Konversi = 95%

t (waktu tinggal) = 1 jam

k = 83,33 L/mol menit

-ra = 0,69 kmol/jam

V = Fv Cao Xa / (-ra) (Levenspiel, 1999)

= 35,256748 L/jam

= 38,7824 L/jam (Waktu tinggal 10%)

Neraca massa masuk reaktor

Arus 3 T 90 C

Komponen	kg/jam	x	BM	kmol/jam	Cp	Cp.x	p	x.p
NaCl	3276,641997	0,30	84,32	38,86	429,57	128,87	2,163	0,6489
H2O	7645,497994	0,70	18,01	424,51	377,50	264,25	0,997	0,6979
total	10922,13999	1,00				393,12		1,3468

Arus 4

komponen	massa	p	Cp	x	Cp.x	x.p	bm	Kmol
H3PO4	2746,885507	1,834	1093,970182	0,8646409	945,8913554	1,5857514	98	28,029444
H2O	430,0235765	0,997	377,5027992	0,1353591	51,09844178	0,134953	18,01	23,876934
TOTAL	3176,909083			1	996,9897972	1,7207044		

Vmasuktotal (V0) = $\frac{14099,05}{3067,50}$ = 31082,76 lb/jam

191,4123 lb/ft³

= 162,39 ft³/jam

= 4,599 m³/jam

Arus 5 T 90 C

Komponen	kg/jam	x	BM	kmol/jam	Cp	Cp.x	p	x.p
NaCl	163,8320999	0,01	58,45	2,80	5528,29	64,24	2,163	0,0251342
H3PO4	137,3442753	0,01	98,00	1,40	14023,44	136,61	1,834	0,0178657
H2O	8075,521571	0,57	18,01	448,39	4888,82	2800,17	0,997	0,5710523
Na2HPO4	3780,586151	0,27	141,96	26,63	23641,80	6339,42	0,5	0,1340724
HCl	1941,764956	0,14	36,46	53,26	1891,54	260,51	1,18	0,1625133
total	14099,04905	1,00		532,48				0,9106379

Vkeluar total = $\frac{14099,05}{910,64}$ = 31083,05 lb/jam

56,8493 lb/ft³

= 546,76 ft³/jam

= 15,48 m³/jam

Kinetika Reaksi

Perbandingan konsentrasi awal (masuk reaktor), NaCl : H3PO4 = 2:1

Karena prosesnya batch dikontinyukan maka dirancang dengan menggunakan beberapa reaktor (RTB) dipasang paralel dan volume masing-masing reaktor sama. Asumsi-asumsi dalam perhitungan ini:

1. pengadukan sempurna sehingga konsentrasi keluar reaktor sama dengan konentrasi dalam reaktor
2. kecepatan volumetris (Fv) masuk reaktor sama dengan kecepatan volumetris keluar reaktor

Optimasi Reaktor
Tujuan optimasi : mendapatkan jumlah dan volume optimal ditinjau dari harga reaktor
Fv = konstan
Fvo = Fv1 = Fv2 = Fvn (Fogler, 2006)
Persamaan neraca massa
Rate of input - (Rate of output + Rate of reaction) = Rate of accumulation
$Fv \cdot C_{AO} - (Fv \cdot C_{A1} + (-r_{A}) \cdot V) = 0$ (*steady state*)
$Fv\ (C_{AO}-C_{A1}) = (-r_A) \cdot V$
$(-r_A) = k\, C_A C_B$,

sehingga: $(-r_A) = k.(C_{Ao} - C_{Ao}.X_A).(C_{Bo} - C_{Ao}.X_A)$

$(-r_A) = k.C_{Ao}.(1 - X_A).(M.C_{A}o - CAo.X_A)$

$(-r_A) = k.C_{Ao}^2.(1 - X_A).(M - X_A)$

$$V = \frac{F_v(C_{Ao} - C_{A1})}{(-r_A)}$$ maka : $$V = \frac{Fv.X_A}{k\, C_{AO}(1 - X_A).(M - X_A)}$$

Volume sebelum optimasi :

Diketahui :

Konversi = 95%

t (waktu tinggal) = 1 jam

k = 83,33 L/mol menit

-ra = 0,69 kmol/jam

V = Fv Cao Xa / (-ra) (Levenspiel, 1999)

= 35,256748 L/jam

= 38,7824 L/jam (Waktu tinggal 10%)

Perhitungan alat :

V sebuah head = (Vto)
V kedua head = 2(0,000049 D^3)
Volume reaktor (Vi) = Volume shell + Volume head
Volume reaktor = 546,7602 ft^3
V Thorisperical = 0,000049xD^3
karena D=H maka
H=D=8,86 ft

Menghitung volume dan jumlah cairan dalam shell :

V = $\left(\frac{1}{4}\pi D^2 Z_L\right)$

Volume cairan = volume reaktor sebelum overdesign =	15,4825530	m^3
Volume head dasar = 0.000049 D3 =	0,000834564	m^3
volume cairan di sheel = volume cairan - volume head dasar =	15,4817185	m^3

Menentukan tekanan desain :

P operasi = 1 atm

Phidrostatis = ρcamp x g x H = 12877,41 pa

Faktor keamaan = 20%

P desain = 19,51 psia

Menentukan tebal shell :

$$ts = \frac{P.r}{(f.E - 0{,}6.P)} + C$$

Dalam hubungan ini

Ts = tebal shell, in = 0,1575 in

r = jari-jari = 53,18 in

E = effisiensi pengelasan =0,85

C = faktor korosi = 0,125

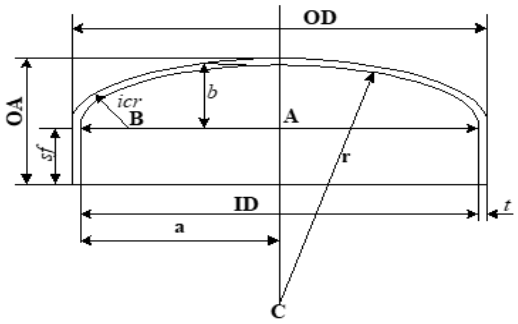
f = tegangan yang diizinkan = 18750 psi

Standarisasi OD

OD = ID + 2 ts
v= 106,37 + 2x0,1875
= 106,7

Menggunakan OD = 96

Perancangan head tangki :



Menentukan dimensi tutup atas dan bawah

$$th = \frac{P.rcW}{(2f.E - 0{,}2.P)} + C$$

th =	Tebal head	= 0,2446	in
W=	Faktor intensifikasi stress		
f=	*Allowable Stress*	= 18750	psi
E=	Joint efficiency	= 0,85	
C=	Faktor korosi	= 0,125	
P=	Tekanan desain	= 19,5072	psi

W= $\frac{1}{4}\left(3+\sqrt{\frac{r}{icr}}\right)$ = 2,036535042

Jadi tinggi dished head = 19,79 in

Perancangan sistem pengaduk :

Diameter impeler (Da)	=	1/3 diameter sheel	=	1/3	x	8,86	=2,95	ft
Lebar blade (W)	=	0,2 diameter impeler	=	0,2	x	2,95	=0,59	ft
Panjang blade	=	0,25 x diameter impeler	=	0,25	x	2,95	=0,74	ft

$$\frac{D_t}{D_i} = 3$$

$$\frac{Z_i}{D_i} = 0{,}75 - 1{,}3$$

$$\frac{Z_L}{D_t} = 2{,}7 - 3{,}9$$

$$\frac{Z_L}{D_t} = 2{,}7 - 3{,}9$$

$$\frac{W}{D_t} = 0{,}1$$

Dt	=	8,8639	ft	=	2,7017	m	=	106,3667	in
Di	=	1/3 x Dt							
	=	1/3 x 4,3885	ft						
	=	2,9546	ft	=	0,9006	m	=	35,4556	in
Zi	=	1,3 x Di							
	=	1,3 x 1,4628	ft						
	=	3,8410	ft	=	1,1707	m	=	46,0922	in
Z_L	=	7,0347	ft	=	2,1442	m	=	84,4168	in
W	=	0,1 x Dt							
	=	0,1 x 4,3885	ft						
	=	0,8864	ft	=	0,2702	m	=	10,6367	in
L	=	0,25 x Di							
	=	0,25 x 1,4628	ft						
	=	0,7387	ft	=	0,2251	m	=	8,8639	in
T	=	0,2 x Di							
	=	0,2 x 1,4628	ft						
	=	0,5909	ft	=	0,1801	m	=	7,0911	in

Menghitung kecepatan pengaduk :

$$\frac{WELH}{2.Di} = \left[\frac{\pi.Di.N}{600}\right]^2$$

WELH = ZL x (e cairan/e air) = 6,4331 ft

N = $\frac{600}{\pi Di}\sqrt{\frac{WELH}{2\ Di}}$ = 67,4781 rpm

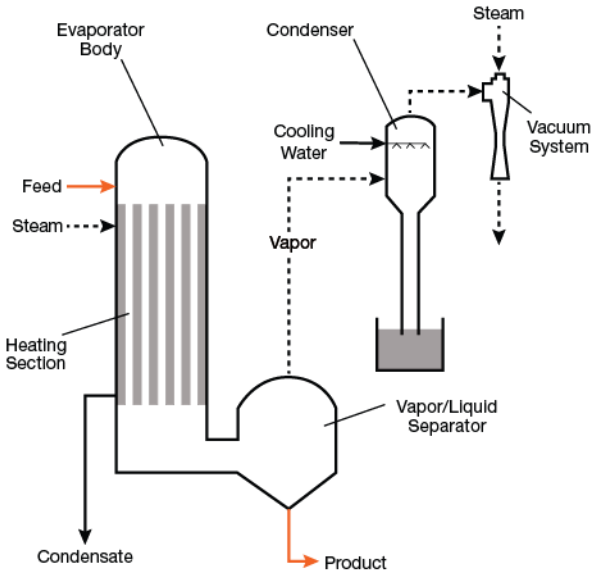
Menentukan daya pengadukan :

Nre = $\frac{N.\rho.D^2}{\mu}$

Besarnya daya yang dibutuhkan untuk pengadukan:

P = $3.52x10^{-3}xNpx\left[\frac{\rho}{62,43}\right]x\left[\frac{N}{60}\right]^3 x\frac{Di^5}{12}$ = 2,87 Hp

EVAPORATOR



Luas perpindahan panas :

$$A = \frac{Q}{UD \times \Delta T}$$ = 46,01303 ft^2

Luas perpindahan panas maksimum = 300 m2 (Ulrich ; T.4-7)

Kondisi tube calandria berdasarkan Badger , hal. 176 :

Ukuran tube = 4 in

Dipilih : Pipa standard 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	=0,089	ft^2

Jumlah tube = $Nt = \frac{A'}{a'_t x\, L}$ = 1551,001 buah

Luas penampang = $A = Nt\, x\, a't$ = 138,0391 ft^2

Diameter evaporator = $D_{evap} = \sqrt{4\, x\, \frac{A}{\pi}}$ = 13,26 ft

Tinggi evaporator berdasarkan dimension ratio:

Asumsi dimension ratio ; H/D = 2

H = 2xD

H = 26,52 ft

Menentukan Tebal :

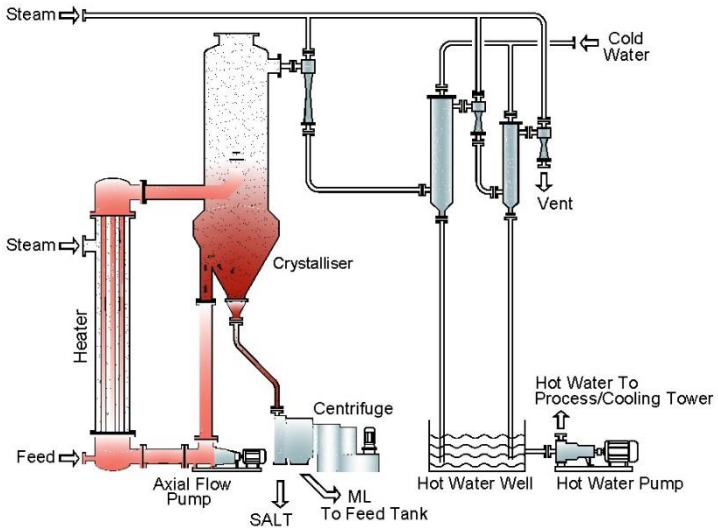
$$ts = \frac{P.r}{(f.E - 0{,}6.P)} + C$$ = 0,138 in digunakan tebal standar 3/16 in

Untuk tebal di atas disamakan dengan tebal tutup bawah karena tutup bawah menerima beban lebih besar

Tebal conical dished (bawah) :

$$Tebal\ conical = \frac{P.D}{2\cos\propto(fE - 0{,}6P)} + C$$ = 0,435 in digunakan tebal standar 0,5 in

KRISTALIZER



Komponen	Intput (kg/jam)	ρ(kg/m3)	(%w/w)	BM	BM camp
	arus 12			kg/kmol	
NaCl	163,8321	2163	0,0249	58,4500	1,4531
H2O	2508,3429	997	0,3806	18,0100	6,8550
H3PO4	137,3443	1834	0,0208	98,0000	2,0424
Na2HPO4	**3780,5862**	500	**0,5737**	**141,9600**	**81,4391**
Total	**6590,1055**	-	**1,0000**	**-**	**91,7896**

$$\rho\ cam = \left[\frac{1}{\frac{0{,}0249}{2163} + \frac{0{,}3806}{997} + \frac{0{,}0208}{1834} + \frac{0{,}5737}{500}} \right]$$

= 644,3393 kg/m^3

=40,2255 lb/ft^3

Rate Bahan Masuk	=	6590,105	kg/jam
	=	14528,69	lb/jam

ρ campuran	=	40,2255	lb/ft³

Flowrate volumetrik (Fv) = $\frac{\text{Rate Bahan Masuk}}{\rho \text{ campuran}}$

= $\frac{14528{,}69 \text{ lb/jam}}{40{,}2255 \text{ lb/ft}^3}$

= 361,1812 ft^3/jam

= 0,1003 ft^3/detik

Waktu kristalisasi	=	1	jam	(time of passes)
Volume bahan	=	361,1812	ft^3/jam	
over design	=	10%		

Maka volume kristaliser = 401,3124 ft^3

Perhitungan dimensi kristaliser :

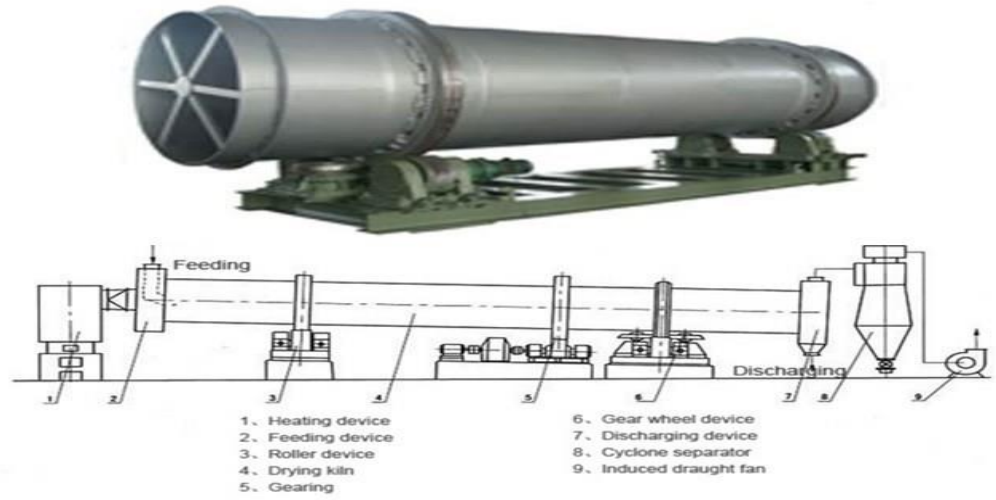
Volume kristaliser = $\frac{m\,x\,D^3}{2} \times \left(1 + \frac{\pi}{4}\right)$ = 224,82 ft

Luas cooling area = $S = V\,x\,\frac{(2+4m)}{mD}$ = 359,88 ft^2/cuft

Power pengadukan :

Volume kristaliser	=	401,3124	ft^3
Power kristaliser	=	6,4210	Hp

ROTARY DRYER



Komponen	Output (kg/jam)	ρ(kg/m3)	(%w/w)	BM	BM
	arus 16			kg/kmol	camp
H2O	250,8343	997	0,0633	18,0100	1,1395
Na2HPO4.7H2O	3713,6067	1680	0,9367	268,0900	251,1277
Total	**3964,4409**	-	**1,0000**	**-**	**252,2672**

$$\rho \text{ cam} = \left| \frac{1}{\frac{0,0633}{997} + \frac{0,9367}{1680}} \right|$$

= 1610,207 kg/m³

= 100,5237 lb/ft³

Rate Bahan Masuk = 3964,44 kg/jam

= 8740,096 lb/jam

ρ campuran = 100,5237 lb/ft³

$$\text{Flowrate volumetrik (Fv)} = \frac{\text{Rate Bahan Masuk}}{\rho \text{ campuran}}$$

$$= \frac{8740,096 \text{ lb/jam}}{100,5237 \text{ lb/ft}^3}$$

= 86,94561 ft³/jam

= 1,4491 ft³/menit

Diameter D = ((4/pi)*A)^1/3

D = 3,3442 ft

= 1,0193 m

= 40,13 in

Perlengkapan Rotary Dryer

Tebal dinding rotary

Untuk diameter = 1,0193 m
diambil tebal = 0,0186 in
= 0,0005 m

Kecepatan putaran rotary dryer

Kecepatan linier batasannya = 0,25 - 0,5 m/detik
diambil v = 0,3 m/detik

Putaran rotary dryer $N = \frac{V}{\pi . D}$

= 0,0937 rps
= 5,6238 rpm
Diambil putaran = 10 rpm

Putaran rotary dryer harus lebih kecil putaran kritis
Putaran kritis = putaran sentrifugal = putaran gravitasi

Vsf < G

$N < G$

$N < \left(\frac{1}{2}\pi\right)\left(\frac{G}{r}\right)^{\frac{1}{2}}$

N = 0,25 rps
15 rpm

N dirancang 10 rpm < 15 rpm (memenuhi)

flight

Perhitungan berdasarkan Perry 7ed; 12-56 :
Ketentuan :
Tinggi flight = 1/12 D ~ 1/8 D
Panjang flight = 0,6 m ~ 2 m
Jumlah flight 1 circle = 2,4 D ~ 3 D

D = 1,0193 m
L = 3,7641 m

Pengambilan data :

Tinggi flight	=	1/8 D	=	0,1274	m
Panjang flight	=	2 m	=	2,0000	m
Jumlah flight 1 circle	=	3 D	=	3,0580	m

Total circle = Panjang drum / Panjang flight
Total circle = 1,8820 buah

Total jumlah flight = Total circle x Jumlah flight tiap 1 circle

Total jumlah flight = 5,7552 buah

Hold up padatan

Volume dryer yang ditempati oleh padatan pada setiap saat berkisar antara 10-15%

Volume dryer (treyball p-692)

diambil 10% volume dryer

Hold up = 0,1*(pi/4)*D^2*L

Hold up = 10,84199 ft^3

waktu rata-rata padatan dalam dryer

feed rata-rata	=	3964,441	kg/jam
feed	=	1000	kg/jam
			ft^3/jam
rata-rata	=	86,94561	

$$\theta = \frac{hold\ up}{\rho rata - rata}$$

$$= \frac{10,84199}{86,94561} = 0,124698 \text{ jam}$$

7,48191 menit

448,9146 detik

Slope / kemiringan rotary dryer

persamaan friedman and marshall

$$\theta = \frac{0,23\,L}{5.N^{0,9}.D} - 0,6\frac{B.L.G}{F}$$

dimana :

Dp	=	diameter paktikel rata-rata, um
F	=	Kecepatan umpan , lb/ft2
N	=	Putaran dryer, rpm
L	=	panjang dryer, ft
G	=	kecepatan massa udara , lb/j ft2
D	=	diameter dryer, ft

perhitungan tebal shell drum :

Rotary Drum memakai shell dari stainless steel (SA-167) tipe 304

dengan strees allowable = 18750

Untuk las dipakai double welded butt joint dengan

effisiensi 80 % Faktor korosi : C = 1/8

Perbandingan tinggi bahan dan diameter drum , H/D = 0,16

(Perry 5ed , tabel 6-52 , hal. 6-87)

D	=	1,0193	m	=	3,3442	ft
H	=	0,5351	ft	=	0,1631	m

D=
1,0193m

Poperasi = atmosferis =		=14,7	psi
Pdesain = 1.1* P operasi =		=16,17	psi
P = tekanan dalam mixer =		=16,17	psi

$$ts = \frac{P.D}{2.f.e - P} + C$$

ts	=	0,1466306	in
dirancang 3/16 in		=0,1875	in
	=	0,0047625	m

Isolasi :
Batu isolasi dipakai setebal 4 in (Perry 7ed ; 12-42)

diameter dalam rotary	=	3,344246	ft
diameter luar rotary	=	3,34504	ft
maka diameter rotary terisolasi	=	4,011707	ft

perhitungan power rotary

$$\text{Perry}^{6ed}\text{, persamaan 20-44} = hp = \frac{N \times (4.75dw + 0{,}1925DW + 0{,}33W)}{100000}$$

dimana :

N =putaran rotary	=	10,0000	rpm
d = diameter shell	=	3,3442	ft
w = berat bahan	=	8740,0956	lb
D = d +2	=	5,3442	ft

Perhitungan berat total :
1) berat shell

$$We = \frac{\pi}{4} \times (Do^2 - Di^2) \times L \times \rho \text{ dengan :}$$

Do = diameter luar shell	=	3,34504	ft
Di = diameter dalam shell	=	3,344246	ft
L = panjang Drum	=	12,34931	ft
ρ = density steel	=	482	lb/cuft

We	=	24,809783	lb

2) berat isolasi

$$We = \frac{\pi}{4} \times (Do^2 - Di^2) \times L \times \rho \text{ dengan :}$$

Do = diameter luar isolasi	=	3,34504	ft
Di = diameter dalam isolasi	=	3,344246	ft
L = panjang isolasi	=	12,34931	ft
ρ = density isolasi	=	19	lb/cuft

We = 0,977979 lb

3) berat bahan dalam drum

Untuk solid hold-up = 15 % (Ulrich T.4-10)

Rate massa	=	8740,096	lb/jam
Berat bahan	=	10051,11	lb/jam

*) berat total = (W)	=	10051,11	lb/jam
Berat lain diasumsikan 15 %, maka berat total =		11558,78	lb/jam

$$\text{Perry}^{6ed}\text{, persamaan 20-44} = hp = \frac{N \times (4.75dw + 0{,}1925DW + 0{,}33W)}{100000}$$

hp = 1,5722 hp

dengan Effisiensi motor = 75 % (Perry 6ed;p.20-37) , maka :

P = 2,0962 hp

18 hp