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REAKTOR

Fungsi : Tempat berlangsungnya reaksi antara Asam Phosphate (H_3PO_4) dengan Sodium Carbonate (Na_2CO_3) membentuk Disodium Phosphate (Na_2HPO_4) dengan kecepatan umpan 10064,1933 kg/jam

Jenis : Reaktor Alir Tangki Berpengaduk.

Fase : Cair – cair

Kondisi Operasi : T = 90°C

P = 1 atm

Konversi = 95 %

- **Tinjauan Kinetika Reaksi**

Mekanisme reaksinya adalah sebagai berikut:

$$\underset{(A)}{H_3PO_4} + \underset{(B)}{Na_2CO_3} \longrightarrow \underset{(C)}{Na_2HPO_4} + \underset{(D)}{CO2} + \underset{(E)}{H_2O}$$

- **Mencari Harga Konstanta Kecepatan Reaksi**

$$k = A\ Exp^{(-E/RT)}$$

$$-ra = k.Ca.Cb$$

$$-ra = \left(\frac{da+db}{2}\right)^2 \frac{N}{10^3}\sqrt{8.\pi.k_o.T\left(\frac{1}{Ma}+\frac{1}{Mb}\right)}.Exp^{-E/RT}.Ca.Cb$$

(Levenspiel.p.24.pers.39)

Dimana:

d_A = Jari-jari Atom A (m) = 0,05 mm (www. Springerlink.com)

d_B = Jari-jari Atom B (m) = 2,75 mm (www. Upspiral com)

N = $6{,}023.10^{23}$ molekul/mol

K_O = $1{,}3.10^{-23}$ J/k

M_A = Berat Molekul A

M_B = Berat Molekul B

T = Suhu (^{O}k)

k $= \left(\frac{da+db}{2}\right)^2 \frac{N}{10^3}\sqrt{8.\pi.k_o.T.\left(\frac{1}{Ma}+\frac{1}{Mb}\right)}Exp^{-E/RT}$

A $= \left(\frac{da+db}{2}\right)^2 \frac{N}{10^3}\sqrt{8.\pi.k_o.T.\left(\frac{1}{Ma}+\frac{1}{Mb}\right)}$

A $= \left(\frac{5.10^{-5}+2{,}75.10^{-3}}{2}\right)^2 \frac{6{,}023.10^{23}}{10^3}\sqrt{8{,}3.\pi.1{,}3.10^{-23}.368\left(\frac{1}{106}+\frac{1}{98}\right)}$

A = $56957{,}75379$ m^2

k = A $Exp^{-E/RT}$

k = 1,3226 /jam

- **Optimasi Jumlah Reaktor**

Tabel A.1 Kecepatan Volume Umpan

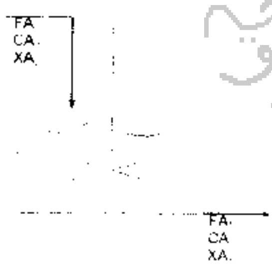
Komponen	BM	Massa (kg/jam)	Mol	Densitas (kg/L)	FV (L/jam)
H_3PO_4	98	2857,9642	29,1629	1,1094	2576,1350
Na_2CO_3	106	3400,3952	32,0797	1,1417	2970,3614
Na_2HPO_4	142	-	-	-	-
CO_2	44	-	-	-	-
H_2O	18	3805,8339	211,4352	0,997951	3813,6481
Total		**10064,1933**			**9368,1445**

- **Menghitung Jumlah Reaktor**

Asumsi : - Pengadukan sempurna sehingga konsentrasi keluar reaktor sama dengan konsentrasi di dalam reaktor.

- Volume 1 reaktor sama dengan volume 2 reaktor.

Jumlah Reaktor = 1



Neraca Massa Reaktor 1

Input- Output + Yang bereaksi = Accumulasi

$FV * CA_0 - FV * CA_1 + (-rA) * V = 0$

$FV * CA_0 - FV * CA_1 = (-rA)$

$FV * CA_0 - FV * CA_0 (1 - XA_1) = (-rA) * V$

$$V_1 = \frac{FV x CA_0 [1 - (1 - XA_1)]}{k x CA}$$

$$= \frac{FV x CA_0 . x . XA_1}{k . x CA}$$

$$= \frac{FV x CA_0 . x . XA_1}{k . x CA_0 (1 - XA)}$$

$$= \frac{FV x . XA_1}{k . x (1 - XA)}$$

Diketahui:

XA1 = 0,95

K = 1,3226 /jam

FV = 9368,1445 L/jam

Persamaan Umum

$$XA_{n-1} = XA_n - \frac{V k (1 - XA_n)}{FV}$$

$$XA = XA1 - \frac{V k (1 - XA1)}{FV}$$

$$0 = 0{,}95 - \frac{V \times 1{,}3224 (1 - 0{,}95)}{9368{,}1445}$$

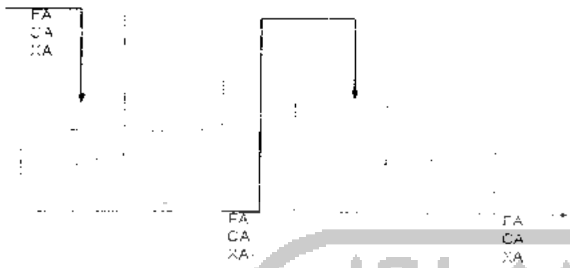
$$V1 = 134579{,}42351 L$$

$$V1 = 3555{,}23319 \; gallon$$

$$t = \frac{V}{\Sigma FV}$$

$$= 14{,}3654 \; jam$$

Jumlah Reaktor = 2



Reaktor 1

$$V_1 = \frac{FV\ x\ XA_1}{k\ x (1 - XA_1)}$$

Reaktor 2

Neraca Massa = Input – Output – Yang bereaksi = Accumulasi

$FV * CA_1 - FV * CA_2 - (-rA) * V_2 = 0$

$$V = \frac{FV\ x (CA_1 - CA_2)}{(-rA)}$$

$$= \frac{FV\ x (CA_1 - CA_2)}{k\ x\ CA_2}$$

$$= \frac{FV\ x\ CA_0\ x\ XA_1}{k\ x\ CA_1}$$

$$= \frac{FV\ x\ CA_0 (XA_2 - XA_1)}{k\ x\ CA_0 (1 - XA_2)}$$

$$= \frac{FV\ x (XA_2 - XA_1)}{k\ x (1 - XA_2)}$$

Diketahui:

XA_1 = 0,7764

XA_2 = 0,95

K = 1,3226 /jam

FV = 9368,1445 L/jam

$$V1 = \frac{FV \times XA1}{k(1 - XA1)}$$

$$= \frac{9368.1445 \times 0.7764}{1.3226(1 - 0.95)}$$

$$= 24594.54486L$$

$$V2 = \frac{FV(XA2 - XA1)}{k(1 - XA2)}$$

$$= \frac{9368,1445(0.95 - 0.7764)}{1.3326(1 - 0.95)}$$

$$= 24592.618856L$$

$$Vrata - rata = \frac{(V1 + V2)}{2}$$

$$= 24593.58186L$$

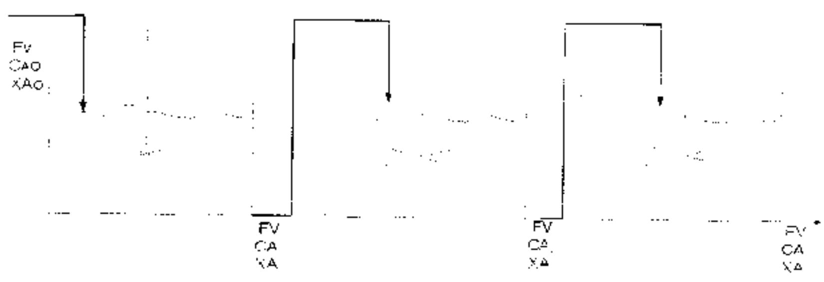
$$= 6496.95722 gallon$$

$$t = \frac{Vrata - rata}{\Sigma FV}$$

$$= \frac{24593.58186}{9368,1445}$$

$$= 2,6252\ jam$$

Jumlah Reaktor = 3



Reaktor 1

$$V_1 = \frac{FV \, x \, XA_1}{k \, x \, (1 - XA_1)}$$

Reaktor 2

$$V_2 = \frac{FV \, x \, (XA_2 - XA_1)}{k \, x \, (1 - XA_2)}$$

Reaktor 3

Neraca Massa = Input – Output – Yang bereaksi = Accumulasi

$FV * CA_2 - FV * CA_3 - (-rA) * V_3 = 0$

$$V_3 = \frac{FV \, x \, (CA_2 - CA_3)}{(-rA)}$$

$$= \frac{FV \, x \, CA_0 \, x \, (XA_3 - XA_2)}{k \, x \, CA_0 \, x \, (1 - XA_3)}$$

$$V_3 = \frac{FV \, x \, (XA_3 - XA_2)}{k \, x \, (1 - XA_3)}$$

Diketahui:

XA_1	= 0,6312
XA_2	=0.8642
XA_3	= 0,95
K	= 1,3226 /jam
FV	= 9368,1445 L/jam

$$V1 = \frac{FV \times XA1}{k(1 - XA1)}$$

$$= \frac{9368{,}1445 \times 0{,}6312}{1{,}3226(1 - 0{,}6312)}$$

$= 12122.74976L$

$$V2 = \frac{FV(XA2 - XA1)}{k(1 - XA2)}$$

$$= \frac{9368.1445(0.8642 - 0.6312)}{1.3226(1 - 0.8642)}$$

$= 12152.93608L$

$$V3 = \frac{FV(XA3 - XA2)}{k(1 - XA3)}$$

$$= \frac{9368.1445(0.95 - 0.8642)}{1.3226(1 - 0.95)}$$

$= 12154.64688L$

$$Vrata - rata = \frac{(V1 + V2 + V3)}{3}$$

$= 12143.44424L$

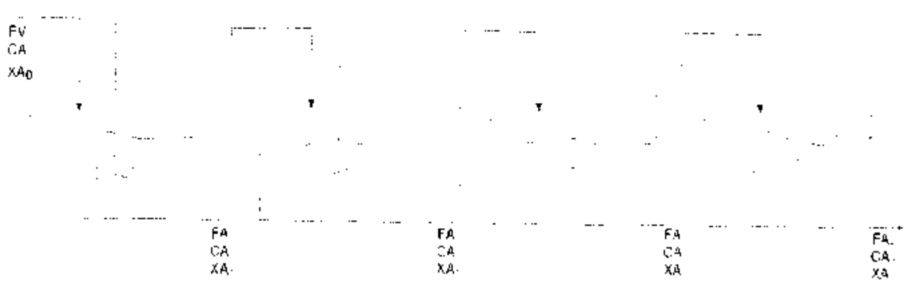
$= 3207.967097 gallon$

$$t = \frac{Vrata - rata}{\Sigma FV}$$

$$= \frac{12143.44424}{9368.1445}$$

$= 1.2962\ jam$

Jumlah Reaktor = 4



Reaktor 1

$$V_1 = \frac{FV \, x \, XA_1}{k \, x \, (1 - XA_1)}$$

Reaktor 2

$$V_2 = \frac{FV \, x \, (XA_2 - XA_1)}{k \, x \, (1 - XA_2)}$$

Reaktor 3

$$V_3 = \frac{FV \, x \, (XA_3 - XA_2)}{k \, x \, (1 - XA_3)}$$

Reaktor 4

Neraca Massa = Input – Output – Yang bereaksi = Accumulasi

$FV * CA_3 - FV * CA_4 - (-rA) * V_4 = 0$

$$V_3 = \frac{FV \, x \, (CA_3 - CA_4)}{(-rA)}$$

$$= \frac{FV \, x \, CA_0 \, x \, (XA_4 - XA_3)}{k \, x \, CA_0 \, x \, (1 - XA_4)}$$

$$V_4 = \frac{FV \, x \, (XA_4 - XA_3)}{k \, x \, (1 - XA_4)}$$

Diketahui:

XA_1	= 0.52709
XA_2	= 0.77638
XA_3	= 0.89426
XA_4	= 0.95
K	= 1.3226 /jam
FV	= 9368.1445 L/jam

$$V1 = \frac{FV \times XA1}{k(1 - XA1)}$$

$$= \frac{9368,1445 \times 0,52709}{1,3226(1 - 0,52709)}$$

$$= 7894,622024L$$

$$V2 = \frac{FV(XA2 - XA1)}{k(1 - XA2)}$$

$$= \frac{9368,1445(0,77638 - 0,52709)}{1,3226(1 - 0,77638)}$$

$$= 7896,220675L$$

$$V3 = \frac{FV(XA3 - XA2)}{k(1 - XA3)}$$

$$= \frac{9368,1445(0,89426 - 0,77638)}{1,3226(1 - 0,89426)}$$

$$= 7896,340796L$$

$$V4 = \frac{FV(XA4 - XA3)}{k(1 - XA4)}$$

$$= \frac{9368,1445(0,95 - 0,89426)}{1,3226(1 - 0,95)}$$

$$= 7896,270595L$$

$$Vrata - rata = \frac{(V1 + V2 + V3 + V4)}{4}$$

$$= 7895,863522L$$

$$= 2085,872965 gallon$$

PERPUSTAKAAN

$$t = \frac{Vrata - rata}{\Sigma FV}$$

$$= \frac{7895.863522}{9368.1445}$$

$= 0.8428\,jam$

- **Menentukan Harga Total Reaktor**

Menggunakan metode *"Six Tenths Factor"*

$$Eb = Ea \cdot \left(\frac{Cb}{Ca}\right)^{0.6}$$ (Timmerhaus, 1991)

Dimana : Ca = Kapasitas alat a

Cb = Kapasitas alat b

Ea = Harga alat a

Eb = Harga alat b

Kondisi operasi = 1 atm = 14.7 lb/in^2

Dipilih bahan *stainless steel*, 50 lb/in^2

Didapat basis harga pada volume 1000 gallons = $ 40.000

(Timmerhause, 1959)

Perhitungan harga reaktor :

1 RATB :

$$\text{Cost B} = \$\,40.000 \left(\frac{35552.23319\,gallon}{1000}\right)^{0.6}$$

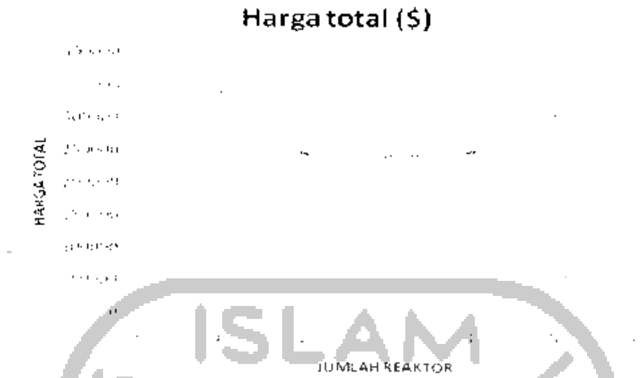
= $ 340863.2047

Data selengkapnya dapat dilihat pada tabel dibawah ini.

Hasil Perhitungan Optimasi Reaktor

Jumlah reaktor	Konversi (x)	Volume (*gallon* US)	Harga /unit ($)	Harga total ($)	Waktu Tinggal (Jam)
1	x_1=0,95	35552,23319	340863,2047	340863,2047	14,3656
2	x_1=0,7764 x_2=0,95	6496,95722	122937,9581	245875,9162	2,6252
3	x_1=0,6316 x_2=0,86428 x_3=0,95	3207,96709	80500,3808	241501,2089	1,2962
4	x_1=0,52709 x_2=0,77638 x_3=0,89426 x_4=0,95	2085,87297	62177,4210	248709,6840	0,8428
5	x_1=0,45067 x_2=0,69827 x_3=0,83427 x_4=0,90897 x_5=0,95	1535,41526	61416,6104	307083,0520	0,6204

Dari tabel diatas, dapat disimpulkan bahwa harga RATB akan yang paling murah apabila digunakan 3 buah RATB,jadi dipilih RATB yang digunakan sebanyak 3 buah.



Grafik Hubungan Jumlah Reaktor Versus Harga ($)

Dari grafik diatas disimpulkan bahwa yang lebih ekonomis adalah penggunaan 3 buah reaktor yang disusun secara seri yaitu dengan volume 3207,967097 gallon dan harga $ 241501,2089.

PERANCANGAN DIMENSI REAKTOR

- **Neraca Massa Tiap Reaktor**

Diketahui: X1 = 0,6316

X2 = 0,86428

X3 = 0,95

Reaktor 1 (R-01)

Komponen	BM	Massa Masuk kg/jam	Massa Keluar kg/jam
H_3PO_4	98	2857.9642	1054.0194
Na_2CO_3	106	3400.3952	1449.1896
Na_2HPO_4	142	-	2613.8792
CO_2	44	-	809.9344
H_2O	18	3805.8339	4137.1707
Total		10064.1933	10064.1933

Reaktor 2 (R-02)

Komponen	BM	Massa Masuk kg/jam	Massa Keluar kg/jam
H_3PO_4	98	1054.0194	388.1094
Na_2CO_3	106	1449.1896	728.9196
Na_2HPO_4	142	2613.8792	3579.1952
CO_2	44	-	298.98
H_2O	18	4137.1707	4259.4807
Total		9254.2589	9254.2589

Reaktor 3 (R-03)

Komponen	BM	Massa Masuk kg/jam	Massa Keluar kg/jam
H_3PO_4	98	388.1094	142.8938
Na_2CO_3	106	728.9196	463.6864
Na_2HPO_4	142	3579.1952	3934.0816
CO_2	44		110.0968
H_2O	18	4259.4807	4304.5203
Total		8955.7049	8955.2789

➢ **Dimensi reactor**

- Kecepatan alir volumetrik umpan, Fv = 9368.1445 L/jam

- Waktu tinggal dalam reaktor (θ)

$$t = \frac{Vrata - rata}{\Sigma FV}$$

$$= \frac{12143,44424}{9368,1445}$$

$$= 1,2968\,jam$$

- **Menentukan Ukuran Reaktor**

Volume cairan dalam reaktor :

$V = V_{rata\text{-}rata}$

= 12143.4442 L

= 3207.9686 gallon

= 12.1434 m^3

Menurut Peter & Timmerhaus (1980).Over design yang direkomendasikan untuk "continous reactor" adalah 20 % :

Volume Reaktor (V_R) = 1.20 (12143.4442) L

= 14527.133 L

= 3849.5623 gallon

= 14.5721 m^3

= 91.664 bbl

Menghitung dimensi reaktor :

Ratio tinggi : diameter = 10 : 7

(D : H = 7 : 10),(**tabel 3.3 brownell&young (p-43)**

Jenis head : **Flanged and Dished Head Torispherical**

Volume head : 0.000049 D^3 **(Brownell and Young, p.88, 5-11)**

Dimana : D = Diameter, inchi

V_H = Volume head, ft^3

Volume reaktor dihitung berdasarkan persamaan :

$$V_R = \frac{\pi D^2 H}{4} + 2\ VH$$

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$$= \frac{\pi D^2 H}{4} + 2\,(0{,}000049\ \text{ft}^3\,)$$

$$= \frac{\pi D^2 (10D/7)}{4} + 0{,}000098 D^3$$

D = 2,3503 m

= 92,5313 in

= 7,7109 ft

H $= \frac{10D}{7}$

= 3,3576 m

= 132,1887 in

= 11,0156 ft

Volume head = 2 x 0,000049 D^3

= 2 x 0,000049 $(92{,}5313)^3$

= 38,8206 in^3

= 0,000636155 m3

Volume cairan dalam reaktor = volume reaktor sebelum over design

= 12143,4442 L

Volume cairan dalam head bottom = volume head / 2

= 0,000636155 m^3 / 2

= 0,0003181 m^3

Digunakan bahan **baja stainless steel SA 167 grade 3**

Tekanan design (P) = 1 atm

Allowable stress (S) = 18750 psia

Efisiensi sambungan (e) = 0,8

faktor korosi (c) = 0,125 in

Diameter (D) = 2,3503 m

= 92,5313 in

Jari-jari tangki (r_i) = D/2

= 2,3503 /2

= 1,1751475 m

= 46,26565 in

Tekanan operasi = 1 atm

= 14,69592 lb/in²

Tekanan hidrostatis (Ph) = ρ.H

= 5,130476 lb/in²

Tekanan design = Tekanan Operasi + Tekanan hidrostatik

= 19,826396 lb/in²

dipilih overdesign reaktor sebesar 20% **(rase, p-208)**

Tekanan Perancangan

P = 1,2 × Pdesign

= 1,2 × 19,826396 lb/in²

= 23,791675 lb/in²

Tebal shell

$$t = \frac{P.ri}{f.E - 0{,}6P} + C$$

$$= \frac{23{,}791675 \times 46{,}26565}{(18750 \times 0{,}8) - (0{,}6 \times 23{,}791675)} + 0{,}125$$

= 0.1984524 in

= 0.0050407 m

ID = 92.5313 in = 2.3503 m

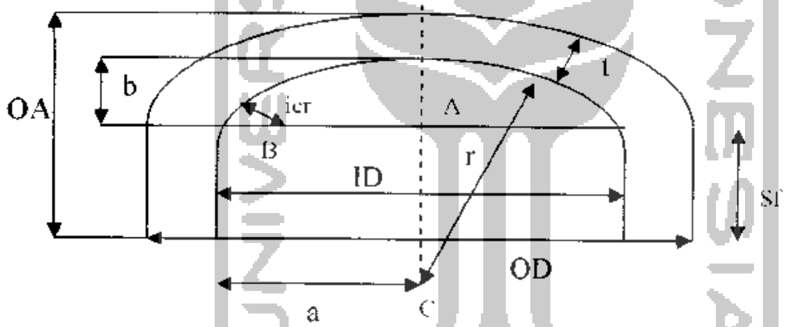
Dipilih tebal shell standar (t) = 1/4 in **(Brownell and Young, p.350)**

OD = ID – 2t

= 85.65235 – 2 (1/4) in

= 92.9063 in ~ 93 in

Menghitung Ukuran Head



Keterangan Gambar :

ID = diameter dalam *head*

OD = diameter luar *head*

a = jari-jari dalam *head*

t = tebal *head*

r = jari-jari luar *dish*

icr = jari-jari dalam sudut *dish*

b = tinggi *head*

sf = *straight flange*

OA = tinggi *head* total

Pertimbangan yang dilakukan dalam pemilihan jenis *head* meliputi :

1. *Flanged & Standard Dished Head*

   Umumnya digunakan untuk tekanan operasi rendah, harganya murah dan digunakan untuk tangki dengan diameter kecil.

2. *Torispherical Flanged & Dished Head*

   Digunakan untuk tekanan operasi hingga 15 bar dan harganya cukup ekonomis.

3. *Eliptical Dished Head*

   Digunakan untuk tekanan operasi tinggi dan harganya cukup mahal.

4. *Hemispherical Head*

   Digunakan untuk tekanan operasi sangat tinggi, kuat dan ukuran yang tersedia

Dipilih bentuk head **"Torispherical dished head" (Brownell and Young, p.85)**

Tebal head dihitung dengan persamaan (Brownell & young,p-138,eq-7.77)

$$t = \frac{P.rc.W}{2.F.E - 0.2P} + C$$

Dari **tabel 5.7 Brownell and Young ; p.91**

icr = 5 2/3 in untuk OD = 93 in

rc = 93 in

$$W = \frac{1}{4}\left(3 + \sqrt{\frac{rc}{icr}}\right)$$ (Brownell & young,p-138,eq-7.76)

$$W = \frac{1}{4}\left(3 + \sqrt{\frac{93}{5.6875}}\right)$$

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= 1.7168416

t $= \dfrac{23.791675 \times 93 \times 1.7168416}{(2 \times 0.125 \times 0.8) - (0.2 \times 23.791675)} + 0.125$

= 0.126649 in

= 0.003217 m

Dipilih tebal head standar 3/16 in **(Brownell and Young ; p.88, table 5-6)**

Penentuan jarak puncak dengan straight flange

Dari **tabel 5-8 Brownell and Young ; p.88**

Straight flange antara 1½ - 2 in

Diambil sf = 2 in

Fig. 5.8 Torispherical p.87 Brownell and Young

a = ID/2

= 46,26565 in

AB = ID/2 – icr

= a – icr

= 40,57815 in

BC = r – icr

= 87,3125 in

AC = $\sqrt{(BC^2 - AB^2)}$

= 77,310325 in

b = r – AC

= 15,689675 in

OA = b + sf − t head

= 17,877175 in

Jadi tinggi head = OA

= 17,877175 in

= 0,445408 m

Tinggi Reaktor = tinggi shell + 2 (tinggi head)

= 4,2657605 m

Menghitung tinggi larutan dalam reaktor

Luas penampang reaktor (A) :

A $= \frac{\pi}{4} ID^2$

$= \frac{\pi}{4}(2,3503)^2 m$

= 4,336269 m²

= 46,67521 ft²

Volume Head Bawah = 0,000049 ID³ **(p.88, table 5-11, Brownell and Young)**

= 0,000049.(2,3503)³

= 0,000636159 m³

Volume larutan pada bagian shell reaktor

= volume larutan dalam reaktor – volume head bawah

= 14,57146384 m³

Tinggi larutan dalam bagian shell reaktor

= Volume larutan / Luas penampang

$$= \frac{14{,}57146384 m^3}{4{,}336269 m^2}$$

= 2,800425624 m

Tinggi larutan dalam shell dan head bawah

= Tinggi larutan dalam shell + Tinggi head bawah

= 3,268793 m

Volume shell = A x Tinggi shell

= 14,559458 m^3

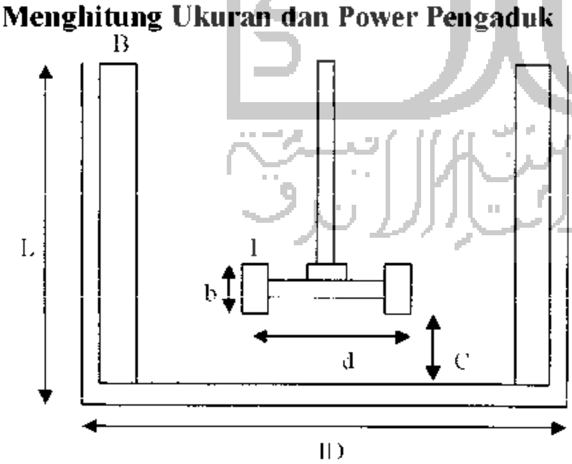
Volume Total Head = 2. Volume head bawah

= 0,001272319 m^3

Volume reaktor = Volume shell + Volume total head

= 14,56073053 m^3

Menghitung Ukuran dan Power Pengaduk



Keterangan :

ID = diameter dalam reaktor

d = diameter pengaduk

l = panjang sudu pengaduk

b = lebar sudu pengaduk

C = jarak pengaduk dengan dasar tangki

B = lebar *baffle*

L = tinggi cairan

Digunakan pengaduk jenis turbin dengan 6 sudu (*six Blades Turbine*), karena turbin memiliki *range* volume yang besar dan dapat digunakan untuk kecepatan putaran yang cukup tinggi.

Data pengaduk diperoleh dari Brown "*Unit Operation*" hal. 507.

Ukuran pengaduk :

- Diameter pengaduk (d)

$$d = \frac{ID}{3} = \frac{92,5313}{3} = 30,84 \text{ in} = 0,78 \text{ m} = 2,57 \text{ ft}$$

- Lebar sudu pengaduk (wi)

$$wi = \frac{d}{5} = \frac{92,5313}{5} = 6,17 \text{ in} = 0,16 \text{ m}$$

- Panjang sudu pengaduk (L)

$$L = \frac{d}{4} = \frac{92,5313}{4} = 7,71 \text{ in} = 0,20 \text{ m}$$

- Lebar *baffle* (wb)

$$wb = \frac{ID}{10} = \frac{92,5313}{10} \text{ in} = 9,25 \text{ in} = 0,24 \text{ m}$$

- Jarak pengaduk dengan dasar tangki (Zi)

$$\frac{Zi}{d} = 0,75 - 1,3 \text{ : dipilih } 3/4$$

Kecepatan putaran pengaduk :

$$N = \frac{600}{\pi . d} \sqrt{\frac{WELH}{2.d}}$$

$$= 111.92 \text{ rpm}$$

Dipakai motor Fixed Speed Belt (single reduction gear with V belt) dengan kecepatan putaran standard N = 125 rpm (Wallas, p- 288). keuntungan memakai motor jenis ini adalah harganya murah dan mudah mengganti bagian-bagian yang rusak.

Menghitung Luas permukaan dalam & Luas permukaan luar

Luas permukaan dinding dalam

- Luas dinding shell (Asi) = π.ID.H
  = 24.77889326 m^2
- Luas dinding head (Ahi) = $\frac{2(1.22\pi)}{400}$
  = 0.346747135 m^2
- Luas Total = Asi + Ahi
  = 25.12564039 m^2

Luas permukaan dinding luar

- Luas dinding shell (Aso) = π.(ID+ts).H
  = 24.77889326 m^2
- Luas dinding head (Aho) = $\frac{2 \times 122}{4(ID + 2th)^2}$
  = 10.98269175 m^2

- Luas Total = Aso + Aho

= 35,76158501 m^2

Menghitung Power Pengaduk (P)

$$P = \frac{Np.\rho.N^3.d^5}{g_c}$$ (Brown, "*Unit Operations*" hal.508)

Dimana :

P	= daya pengaduk, lb.ft/s	
Np	= power number	
N	= kecepatan putar pengaduk	= 125 rpm = 2,08 rps
ρ	= densitas campuran	= 1,07 g/cm^3
d	= diameter pengaduk	= 78,34 cm
g_c	= gravitasi	= 32,17 ft.lbm/s^2.lbf
μ	= 0,17 gr/cm.s	

$$N_{Re} = \frac{N.d^2.\rho}{\mu}$$

$$= \frac{2,08 rps x (78,34)^2 m x 1,07 g/cm^3}{0,17 gr/cm.s}$$

= 79.633,77489

Dari fig. 10.6 Wallas, diperoleh Np = 2,5

$$P = \frac{Np x \rho x N^3 x d^5}{gc}$$

$$P = \frac{2,5 x (1,07 g/cm^3) x (2,08 rps)^3 x (78,34 cm)^5}{32,17 ft.lbm/s^2.lbf}$$

= 71.671.635.248 g.cm^2/s^3

= 7,17 kW

Effisiensi motor penggerak (η) = 80 %

Daya penggerak motor = $\frac{P}{\eta}$

$= \frac{7{,}17 kW}{0{,}8}$

= 8,96 kW

= 12,01 Hp

Maka dipakai motor dengan daya = 15 Hp *(standar NEMA Rase&Barrow 1957, p-358)*

➢ **NERACA PANAS**

Data panas pembentukan (ΔHf)

Tabel A.3 Data Panas Pembentukan (ΔHf)

Komponen	ΔHf_{298}(kkal/kmol)
H_3PO_4	-306,2
Na_2CO_3	-269,46
Na_2HPO_4	-86,56679
CO_2	-94,009539
H_2O	-68,284787

Heat capacity at constant pressure (kcal/kgK) pada suhu 95°C

Cp H_3PO_4 = 0,00038 Kcal/Kg.K

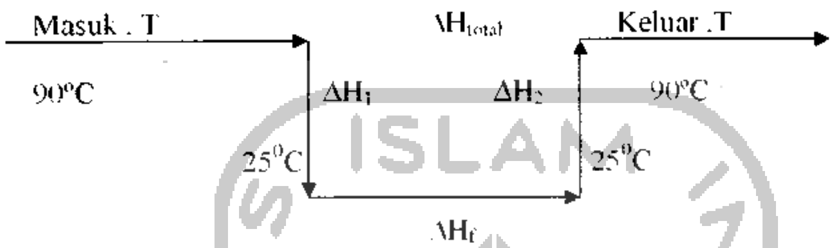
Cp Na_2CO_3 = 0,000272642 Kcal/Kg.K

Cp Na_2HPO_4 = 0,000609859 Kcal/Kg.K

Cp CO_2 = 0,000231318 Kcal/Kg.K

Cp H_2O = 0,999640152 Kcal/Kg.K

Entalpi reaksi pada sembarang suhu dapat dituliskan dengan persamaan:



Panas umpan masuk (ΔH_1)

Komponen	Massa Kg	Cp Kcal/kg.K	ΔT K	ΔH1=m.Cp.ΔT Kcal
H3PO4	2857.9642	0.00038	-65	-70.59171574
Na2CO3	3400.3952	0.00027264	-65	-60.26088563
H2O	3805.8339	0.99964015	-65	-247290.1849
Total	10064.1933			-247421.0375

Panas umpan keluar (ΔH_2)

Komponen	Massa Kg	Cp Kcal/kg.K	ΔT K	ΔH2=m.Cp.ΔT Kcal
H3PO4	1054.0194	0.00038	65	26.03427918
Na2CO3	1449.1896	0.00027264	65	25.68214681
Na2HPO4	2613.8792	0.00060986	65	103.6163541
CO2	809.9344	0.00023132	65	12.17790636
H2O	4137.1707	0.99964015	65	268819.3269
Total	10064.1933			268986.8376

Panas reaksi (ΔHr) ----------> Reaktor 1

ΔHf = ΔHf(produk) - ΔHf(reaktan)

= 326,798884 kkal/kmol

H_3PO_4 yang bereaksi = H_3PO_4 masuk reactor(mol) x Konversi

= 29,1629 × 63,12%

= 18,40762248 kmol

ΔHf @298K = ΔHf x H_3PO_4 yang bereaksi

= 326,79884 × 18,40762248

= 6015,590484 kkal

ΔHr = $\Delta H1$ − ΔHf@298K + $\Delta H2$

= -247421,0375 + 6015,590484 + 268986,8376

= 27581,3906 kkal

Reaksi berjalan secara Endothermis, tetapi dipertahankan suhu agar isothermal (pada suhu 90°C) maka diperlukan media pemanas (koil pemanas).

Neraca panas Overall

Sumber Panas	Masuk (kkal)	Keluar (kkal)
Umpan masuk (ΔH_1)	247421,0375	-
Produk keluar (ΔH_2)	-	268986,8376
Panas Reaksi (ΔHr)	-	27581,3906
Panas steam (Q)	49147,1907	-
Total	296568,2282	296568,2282

Merancang Coil Pemanas Reaktor

Menghitung Coil Pemanas

Perancangan Pemanas reaktor

Jenis : coil

Dipilih pemanas : steam

Diambil : suhu steam = 120 °C

suhu larutan = 90 °C

Diketahui:

Q = 49147,1907 Kkal

$$W = \frac{Q}{cp.\Delta T} = 1638,82942 \text{ Kg/jam}$$

Untuk pemakaian koil dalam tangki berpengaduk digunakan persamaan:

$$\left(\frac{h.Dj}{k}\right) = 0.87\left(\frac{Lp^2.Nr.\rho}{\mu}\right)^{0.62}\left(\frac{Cp.\mu}{k}\right)^{\frac{1}{3}}\left(\frac{\mu b}{\mu w}\right)^{0.14}$$ (perry V.pers 10-79,p-10-17)

Dengan:

h = heat transfer coefisien dalam coil

Dj = Diameter dalam vessel

Lp = Diameter impeller

Cp = Kapasitas panas bahan

μb = Viskositas bulk

μw = Viskositas air = 0,22 (fig 3-45 perry V)

μ = Viskositas larutan

k = Konduktifitas panas bahan

Tabel Kapasitas Panas

Komponen	Massa kg/jam	(m) cp	fraksi berat wi	wi/m	Cp Kkal/kg.K	Cp*wi
H_3PO_4	2857.9642	7	0.2839735	0.040568	0.00038	0.000108
Na_2CO_3	3400.3952	44	0.3378706	0.007679	0.000273	9.21E-05
H_2O	3805.8339	1.05	0.3781559	0.360148	0.99964	0.37802
Total	10064.1933			0.408395		0.3782

Tabel Konduktivitas Panas

$$k^* = \left(\frac{0.869 \, Cp.\rho^{4/3}}{M^{1/3}} \right)$$ (perry V.pers 3-83.p-3-242)

Komponen	Cp Kkal/kg.K	ρ Kg/L	BM kg/kmol	k*
H_3PO_4	0.00038	1.1094	98	8.23E-05
Na_2CO_3	0.0002726	1.1417	106	5.97E-05
H_2O	0.9996402	0.99795	18	0.330561
Total				0.3307

Untuk menghitung k campuran digunakan persamaan:

$$km = kc\left(\frac{2.kc + kd - 2\phi d(kc - kd)}{2.kc + kd + \phi d(kc - kd)} \right)$$ (perry V.pers 3-93.p-3-243)

Dengan:

Kc = harga k fase kontinyu (H_2O) = 0.3305

Kd = harga k fase diskontinyu = 7.0997E-05

Θd = fraksi volume fase diskontinyu = 0.296456

Jadi :

$$km = 0.3305\left(\frac{2.0.3305 + (7.0997E\text{-}05) - 0.296456(0.3305 - (7.099E\text{-}05))}{2.0.3305 + 7.099E\text{-}05 + 0.296456(0.3305 - (7.0997E\text{-}05))} \right)$$

Km = 0.273057356 BTU/ft^2 jam ^{0}F

- **Menghitung hi dan hio**

$$\left(\frac{Lp^2.Nr.\rho}{\mu}\right) = 563025.2833$$

Dari grafik 20-2, p-718, Kern diperoleh :

$$J = \frac{h.Dj}{k}\left(\frac{Cp.\mu}{k}\right)^{\frac{1}{3}}\left(\frac{\mu}{\mu w}\right)^{0.14} = 2500$$

$$ho = \frac{k}{Dj}\left(\frac{Cp.\mu}{k}\right)^{\frac{1}{3}}\left(\frac{\mu}{\mu w}\right)^{0.14}.J = 937.090299$$

Untuk steam dalam coil, maka hoi = 1500 BTU/ft^2 jam ^{0}F

- **Menghitung Clean Overall Coeficient**

$$Uc = \left(\frac{hoxhio}{ho+hio}\right) \quad \text{(kern , p-723)}$$

$$Uc = \left(\frac{935.0902299x1500}{937.090299+1500}\right)$$

$$Uc = 576.7678978$$

Dari kern, p-840 :

Hot fluid = Steam

Cold fluid = aqueous solution

Maka : U_D = 200 – 700,dengan R_D(Dirt Factor) = 0.001

- **Cek harga UD**

- Untuk coil (kern p-723)

$$h_i = \frac{1}{RD}$$

$$h_D = \frac{1}{0.001} = 1000$$

$$U_D = \frac{(U_C . h_D)}{(U_C + h_D)}$$

$$U_D = \frac{(576,7678978.1000)}{(576,7678978 + 1000)}$$

UD = 365,7912484 (Memenuhi)

- **Menghitung Luas Perpindahan Panas**

$$A = \frac{Q}{(U_D . \Delta T)}$$ **(Kern,p-107)**

$$A = \frac{49147,1907}{(365,7912484 \times (120 - 90))}$$

$A = 4,47862\ m^2$

$A = 48,2074535\ ft^2$

- **Menghitung Panjang Coil**

Coil menggunakan pipa baja dengan OD = 1 ¼ in ,16 BWG.Maka:

At = 0,2932 ft^2/lit ft **(Kern,table:10,p-107)**

Jumlah lilitan coil = 1 buah , maka:

$$Panjang\ coil = \frac{A}{(A_T . Jumlah\ coil)}$$

$$Panjang\ coil = \frac{48,2074535\ ft^2}{(0,2932\ ft^2/linft\ .1)}$$

Panjang Coil = 164,4183269 ft

= 50,115 m

- **Menghitung Panjang Coil**
  - Jarak antar lilitan = 3 1/8 in = 0,079 m
  - Jarak dari dinding tangki ke coil = 30 cm =0,3 m

- Diameter lilitan coil = ID – (2 x jarak diding tangki ke coil)

  = 2,3503 m – (2 x 0,3) m

  = 1,7503 m

- Keliling lilitan = π x D

  = 3,14 x 1,7503 m

  = 5,495942 m

- Jumlah lilitan = panjang coil : keliling lilitan

  = 9,118492525 lilitan

  = 10 lilitan

Grafik Hubungan BEP & SDP terhadap Kapasitas Produksi

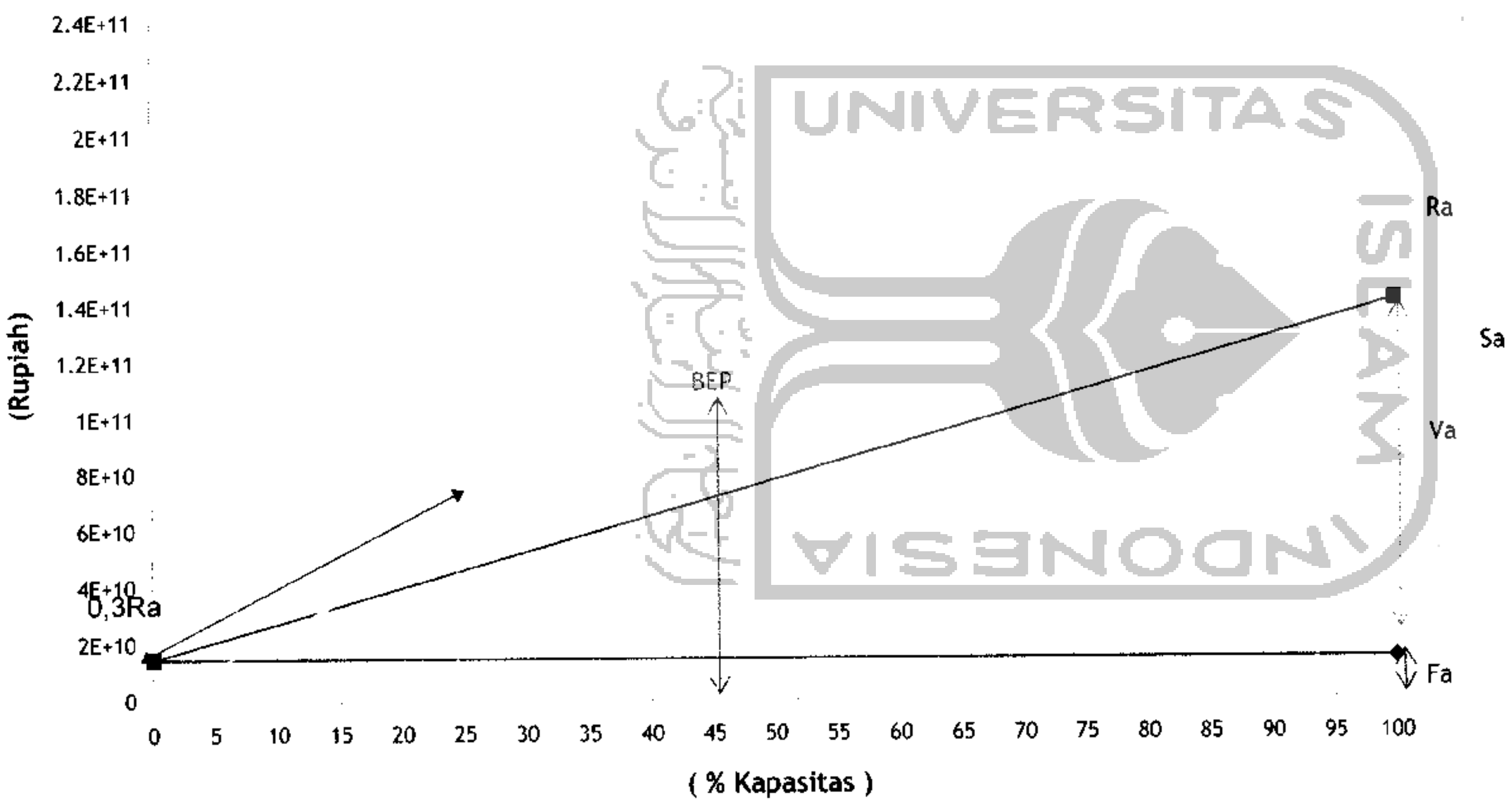
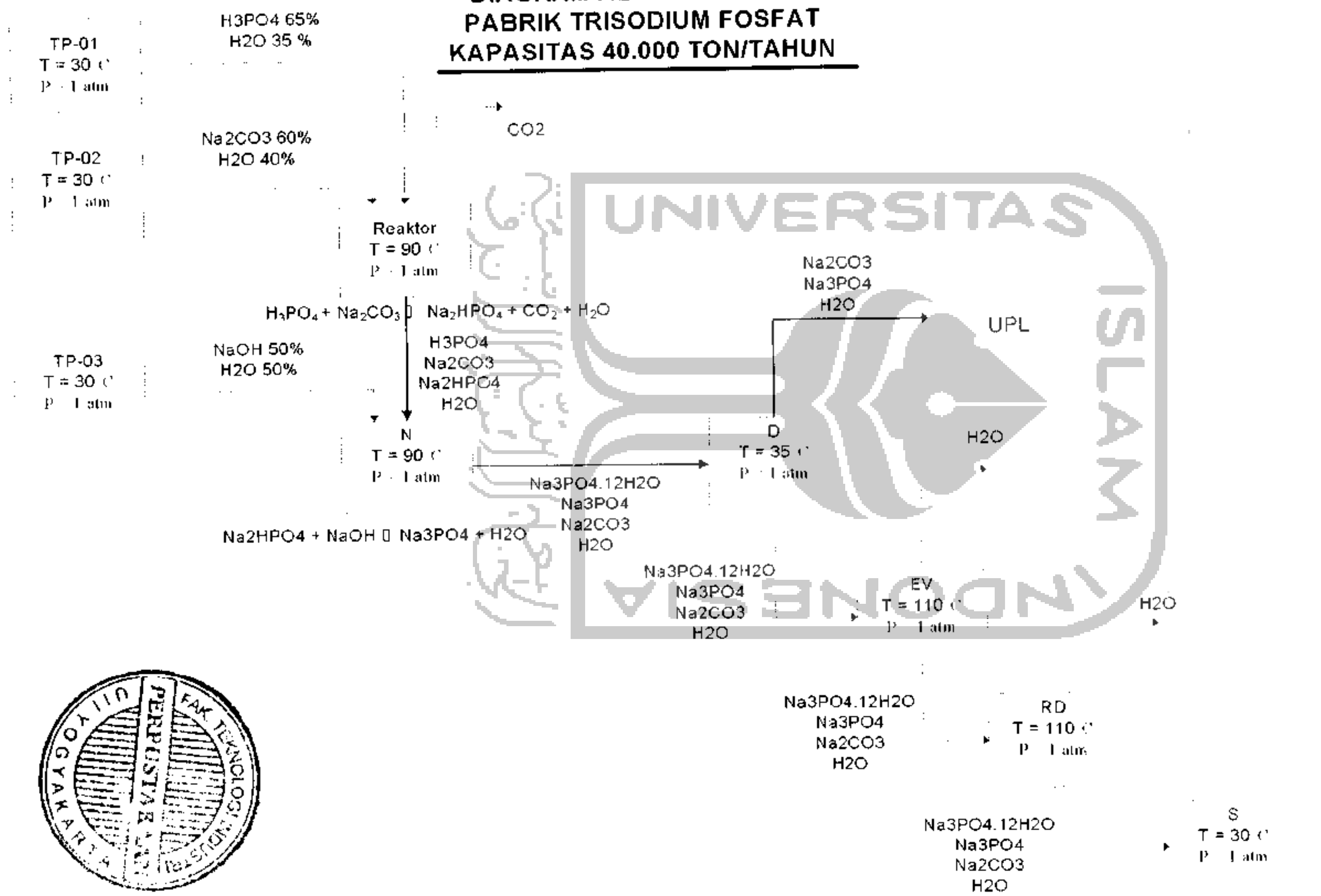
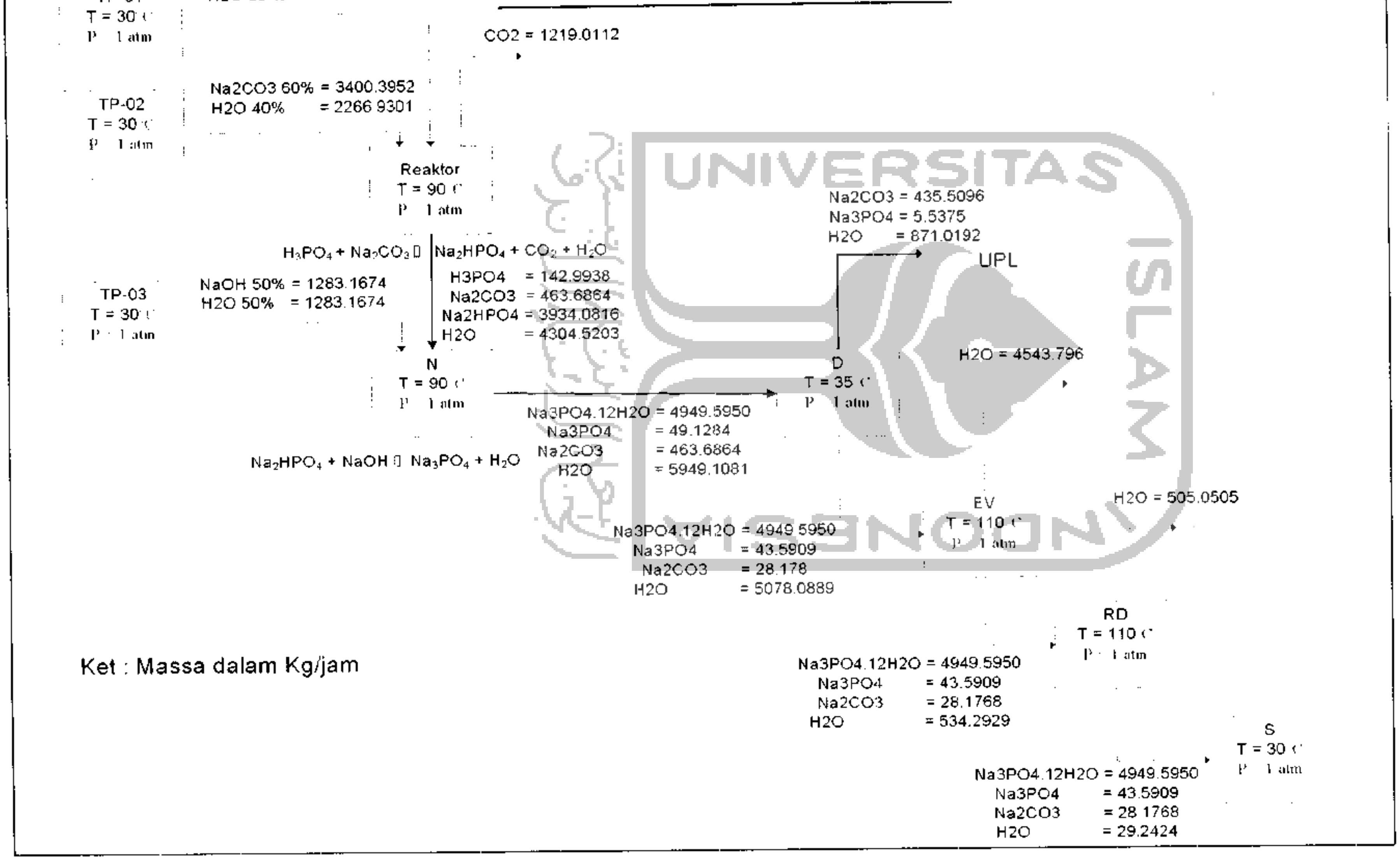


DIAGRAM ALIR KUALITATIF PABRIK TRISODIUM FOSFAT KAPASITAS 40.000 TON/TAHUN



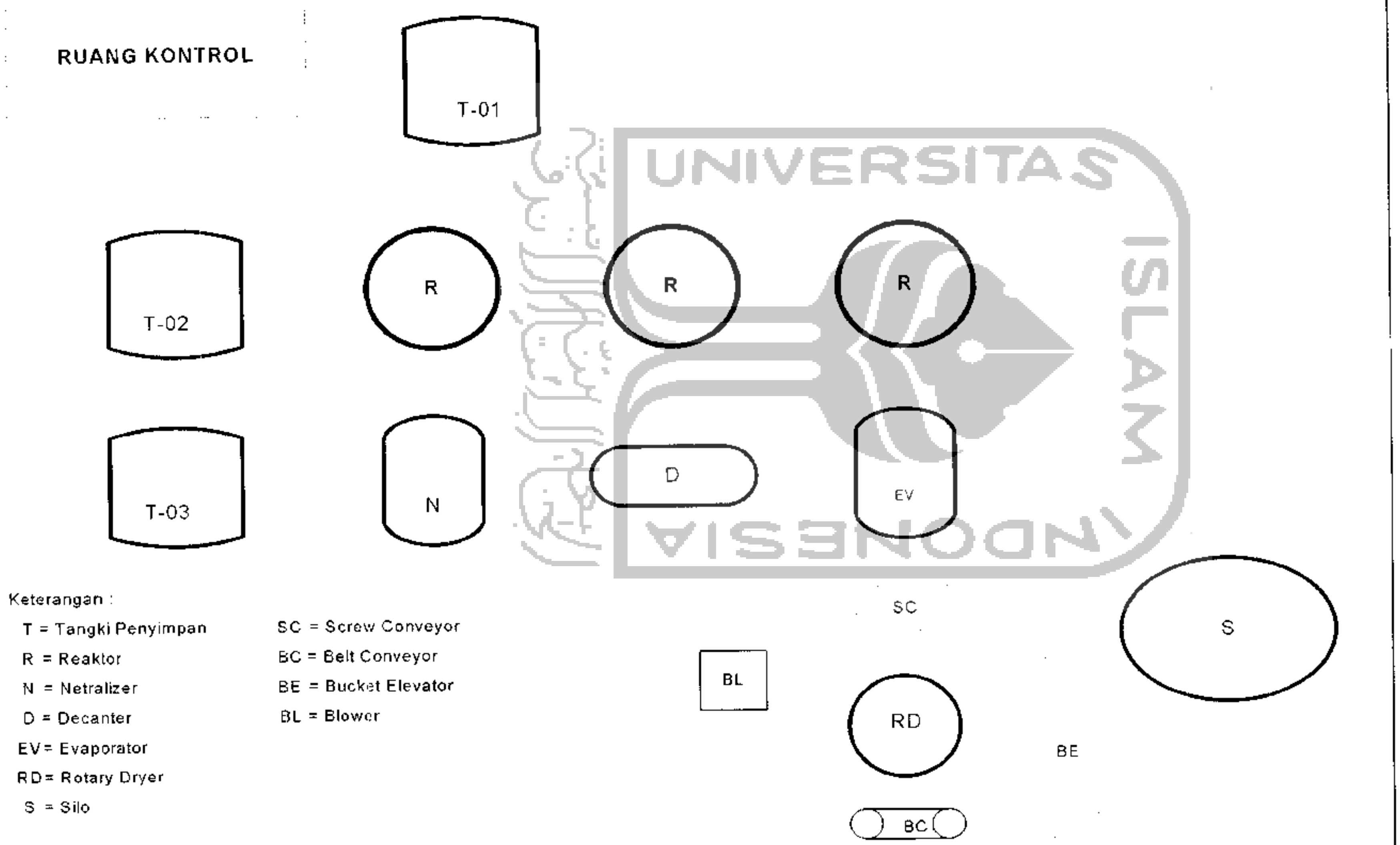
FAK. TEKNOLOGI INDUSTRI PERPUSTAKAAN UII YOGYAKARTA

DIAGRAM ALIR KUANTITATIF
PABRIK TRISODIUM FOSFAT



Ket : Massa dalam Kg/jam

LAY OUT ALAT PROSES



Keterangan :

T = Tangki Penyimpan
R = Reaktor
N = Netralizer
D = Decanter
EV = Evaporator
RD = Rotary Dryer
S = Silo

SC = Screw Conveyor
BC = Belt Conveyor
BE = Bucket Elevator
BL = Blower

PROCESS ENGINEERING FLOW DIAGRAM
UTILITAS
PABRIK TRISODIUM FOSFAT