LAMPIRAN A

REAKTOR

Tugas : Tempat berlangsungnya reaksi antara Asam Asetat dan Anilin menjadi Asetanilida.

Alat: Reaktor Alir Tangki Berpengaduk

Alasan pemilihan:

1. Terdapat pengaduk sehingga suhu dan komposisi campuran adalah reaktor yang harus selalu homogen bisa terpenuhi.
2. Fase reaktan adalah cair sehingga memungkinkan penggunaan RATB.
3. Pengontrolan suhu mudah, sehingga kondisi operasi yang isothermal bisa dipenuhi.
4. Mudah dalam melakukan pengontrolan secara otomatis sehingga produk lebih konsisten dan biaya operasi lebih rendah.

Tujuan perancangan:

1. Menghitung neraca massa
2. Menghitung neraca panas
3. Perancangan reaktor

Kondisi operasi :

P = 2,5 atm

T = 150 °C

DATA :

Raw material:

Asam asetat CH_3COOH

Kemurnian : 99,8 %

Anilin C_6H_5NH2

Kemurnian : 98%

Spesifikasi produk Asetanilida yang diinginkan $C_6H_5NHCOCH_3$ = 98 %

Konversi reaksi 85 %

Komponen	**BM**
CH_3COOH	60.0526
C_6H_5NH2	93.1283
$C_6H_5NHCOCH_3$	135.1656
H2O	18.0153

A. Kinetika Reaksi

Reaksi : $C_6H_5NH_{2\,(l)} + (CH_2CO)_2O_{(l)} \rightarrow C_6H_5NHCOCH_{3\,(s)} + H_2O_{(l)}$

a + b ----------> c + d

Persamaan Laju Reaksi

Reaksi dianggap berorder 2 masing-masing terhadap a dan b

(-ra) = k.Ca.Cb

Dengan : (-ra) = laju reaksi $C_9H_8O_4$, kmol/m^3.jam

k = konstanta laju reaksi, m^3/kmol.jam.

Ca = konsentrasi C_7H_6O3, kmol/m^3.

Cb = konsentrasi C4H6O3, kmol/m^3.

Berdasarkan referensi disebutkan :

1. Konversi sebesar = 0,85

2. Reaksi berlangsung dalam reaktor alir tangki berpengaduk

3. Waktu reaksi yang dibutuhkan = 9,8 jam

Menghitung konsentrasi awal a (Ca0) :

komponen	BM (kg/kmol)	rho(kg/m3)	Fm (kmol/jam)	Fw (kg/jam)	Fv (m3/jam)	%mol
asetanilida	135,1656	1120.000	0.0000	254.2620	0.2270	0.0000
anilin	93,1283	1020.000	26.6321	2480.2023	2.4316	0.2663
asam asetat	60,0526	1050.000	28.3086	1700.0033	1.6191	0.2831
air	18,0153	1000.0000	45.0635	811.8321	0.8118	0.4506
Total		4190.0000	100.0042	5246.2998	5.0895	1.0000

$$Ca\,0 = \frac{Fm}{Fv_{total}}$$

Sehingga : Ca0 = 5,2328 kmol/m^3

Cb0 = 5,5622 kmol/m^3

M = Cb0/Ca0 = 1,0630

Diketahui :

Xa = 0,85

K 150 = 0,0018 liter/mol.menit (Kirk.,and Othmer, 1981)

= 0,1086 m^3/kmol.jam

Menghitung laju reaksi :

-rA = k . Ca . Cb

-rA = k.Cao^2.(1 – X).(M – X)

-rA = 0.0950 kmol/m3.jam

B. Perancangan Reaktor

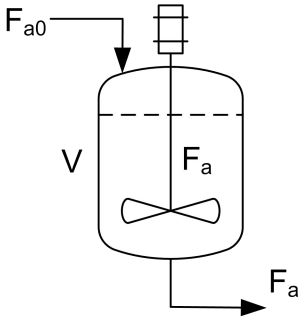
Model Matematis Perancangan Reaktor

Asumsi : 1. Isothermal

2. Pengadukan sempurna

3. Laju alir volumetrik tetap

4. Steady state



Neraca Massa A

Laju A masuk - Laju A keluar - Laju reaksi A = Laju Akumulasi

Fv. Ca in - Fv Ca out +(-ra)V = 0

Fv. Ca in - Fv Ca out = (-ra)V

Fv(Ca in -Ca Out) = (-ra)V

V = Fv(Ca.in -Ca.out) / (-ra)

V = Fv(Ca0- Ca0(1-Xa)) / (-ra)

V = Fv (Ca0. Xa) / (-ra)

V = Fv (Ca0. Xa) / k. Ca.Cb

V = Fv (Ca0. Xa) / k. (Ca0 (1 - Xa)) . (Cb0 - Ca0. Xa))

V = Fv .Xa / k. Ca0. (1- Xa) . (M -Xa)

Diketahui :

Fv = 5.0895 m^3/jam

Ca0 = kmol/m^3

M = Cb0/Ca0 = 1,0630

Xa = 0,85

K 150 = 0,0018 liter/mol.menit (Kirk.,and Othmer, 1981)

= 0,1086 m^3/kmol.jam

Sehingga diperoleh :

V = 238.3330 m^3

t = 46.8286 jam

Menetukan optimasi jumlah reaktor

1. Jumlah Reaktor = 1

X_{A1} = 0,85

k = 0,1086 m^3/kmol.jam

Fv = 5.0895 m^3/jam

Ca0 = 5,2328 kmol/m^3

Persamaan Umum

$$X_{An-1} = X_{An} - \frac{V.k.CAo(1 - XAn)(M - XAn)}{Fv}$$

$V_{coba\text{-}coba}$ = 238.3330 m^3 = 62960.91481 gal

$$X_{Ao} = X_{A1} - \frac{V.k.CAo(1-XA1)(M-XA1)}{Fv}$$

$$= 0{,}85 - \frac{238{,}3330 .0{,}1086 .5{,}2328(1-0{,}85)(1{,}0630-0{,}85)}{5.0895}$$

$$= 0$$

t = 46.8286 jam

2. Jumlah Reaktor = 2

X_{A1} = 0,85

k = 0,1086 m^3/kmol.jam

Fv = 5.0895 m^3/jam

Ca0 = 5,2328 kmol/m^3

Persamaan Umum

$$X_{An-1} = X_{An} - \frac{V.k.CAo(1-XAn)(M-XAn)}{Fv}$$

$V_{coba\text{-}coba}$ = 48.5639 m^3 = 12829.2179 gal

$$X_{A1} = X_{A2} - \frac{V.k.CAo(1-XA2)(M-XA2)}{Fv}$$

$$= 0{,}85 - \frac{48{,}5639 .0{,}1086 .5{,}2328(1-0{,}85)(1{,}0630-0{,}85)}{5.0895}$$

$$= 0{,}6768$$

$$X_{Ao} = X_{A1} - \frac{V.k.CAo(1-XA1)(M-XA1)}{Fv}$$

$$= 0{,}6768 - \frac{48{,}5639 .0{,}1086 .5{,}2328(1-0{,}6768)(1{,}0630-0{,}6768)}{5.0895}$$

$$= 0$$

3. Jumlah Reaktor = 3

X_{A1} = 0,85

k = 0,1086 m^3/kmol.jam

Fv = 5.0895 m^3/jam

Ca0 = 5,2328 kmol/m^3

Persamaan Umum

$$X_{An-1} = X_{An} - \frac{V.k.CAo(1-XAn)(M-XAn)}{Fv}$$

$V_{coba\text{-}coba}$ = 24,2793 m^3 = 6413,9122 gal

$$X_{A2} = X_{A3} - \frac{V.k.CAo(1-XA3)(M-XA3)}{Fv}$$

$$= 0,85 - \frac{24,2793.0,1086.5,2328(1-0,85)(1,0630-0,85)}{5.0895}$$

$$= 0,7634$$

$$X_{A1} = X_{A2} - \frac{V.k.CAo(1-XA2)(M-XA2)}{Fv}$$

$$= 0,7634 - \frac{24,2793.0,1086.5,2328(1-0,7634)(1,0630-0,7634)}{5.0895}$$

$$= 0,5713$$

$$X_{A0} = X_{A1} - \frac{V.k.CAo(1-XA1)(M-XA1)}{Fv}$$

$$= 0,5713 - \frac{24,2793.0,1086.5,2328(1-0,5713)(1,0630-0,5713)}{5.0895}$$

$$= 0$$

4. Jumlah Reaktor = 4

X_{A1} = 0,85

k = 0,1086 m^3/kmol.jam

Fv = 5.0895 m^3/jam

Ca0 = 5,2328 kmol/m^3

Persamaan Umum

$$X_{An-1} = X_{An} - \frac{V.k.CAo(1-XAn)(M-XAn)}{Fv}$$

$V_{coba\text{-}coba}$ = 15,7910 m^3 = 4171,5407 gal

$$X_{A3} = X_{A4} - \frac{V.k.CAo(1-XA4)(M-XA4)}{Fv}$$

$$= 0,85 - \frac{15,7910 .0,1086 .5,2328(1-0,85)(1,0630-0,85)}{5.0895}$$

$$= 0,7937$$

$$X_{A2} = X_{A3} - \frac{V.k.CAo(1-XA3)(M-XA3)}{Fv}$$

$$= 0,7937 - \frac{15,7910 .0,1086 .5,2328(1-0,7937)(1,0630-0,7937)}{5.0895}$$

$$= 0,6957$$

$$X_{A1} = X_{A2} - \frac{V.k.CAo(1-XA2)(M-XA2)}{Fv}$$

$$= 0,6957 - \frac{15,7910 .0,1086 .5,2328(1-0,6957)(1,0630-0,6957)}{5.0895}$$

$$= 0,4987$$

$$X_{A0} = X_{A1} - \frac{V.k.CAo(1-XA1)(M-XA1)}{Fv}$$

$$= 0{,}4987 - \frac{15{,}7910 \,.0{,}1086 \,.5{,}2328(1-0{,}4987)(1{,}0630-0{,}4987)}{5.0895}$$

$$= 0$$

Menghitung Harga Total Reaktor dengan Menggunakan Persamaan " Six Tenth Factor"

H = n. K. $V^{0,6}$; Karena K = Konstanta, maka

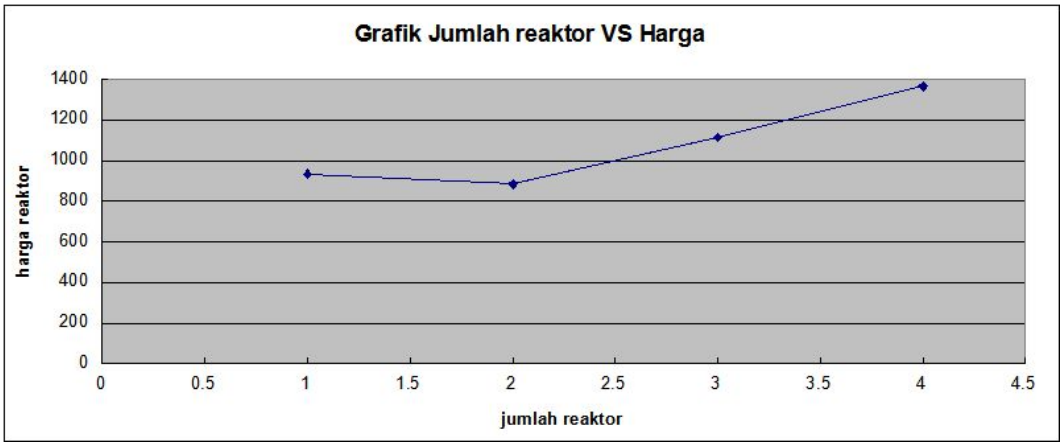
H = n . $V^{0,6}$

(Data Harga Total Tiap Reaktor ditampilkan pada Tabel Optimasi Reaktor)

Tabel Hasil Perhitungan Optimasi Reaktor

N	Volume (gallon)	Volume Total (gallon)	cost tiap reaktor	cost total reaktor
1	89378.74241	89378.74241	934.847011	934.847011
2	12829.21794	25658.43589	442.1179089	884.2358178
3	6413.912211	19241.73663	372.0031005	1116.009302
4	4171.540684	16686.16273	341.5182252	1366.072901

Grafik Hubungan Jumlah reakor dan harga reakor ($)



Menghitung Neraca Massa Tiap Reaktor

Reaktor I

Konversi X_{A1} = 0,65= 65 %

No. Arus	4		
Total flowrate	5246.2998	kg/h	
komponen	%massa	kg/h	kmol/h
asetanilida (l)	0.4912	2576.7443	19.0636
asetanilida (s)	0.0000	0.0000	0.0000
air	0.2137	1121.3796	62.2460
aniline	0.1677	880.0254	9.4496
asam asetat	0.1274	668.1505	11.1261
total	1.0000	5246.2998	101.8853

Reaktor II

Konversi X_{A1} = 0,85= 85 %

No. Arus	5		
Total flowrate	5246.2998	kg/h	
komponen	%mol	kg/h	kmol/h
asetanilida (l)	0.2659	3662.4160	27.0958
asetanilida (s)	0.0000	0.0000	0.0000
air	0.6898	1266.0812	70.2782
aniline	0.0139	132.0038	1.4174
asam asetat	0.0304	185.7987	3.0939
total	1.0000	5246.2998	101.8853

PERANCANGAN REAKTOR 1

Dimensi Reaktor

Diameter dan Tinggi Reaktor Menurut Peters dan Timmerhaus (1980), overdesign yang direkomendasikan untuk "Continuous Reactor" adalah 20 %. Jadi volume masing-masing reaktor adalah :

Fv = 5,0895 m^3/jam

t = 9,8 jam

V1 = V2 = 48.5639 m^3

V_R = 1.2 Vi = 58.2767 m^3

Spesifikasi Reaktor :

$$V_R = V_{SHELL} + V_{BOTTOM} + V_{HEAD}$$

Dirancang : D = H

Perbandingan tinggi tangki dengan diameter tangki (Hs : D) = 1 : 1

Volume Shell :

$$V_{SHELL} = \frac{\pi * D^2}{4} * H_S$$

$$V_{SHELL} = \frac{\pi * D^3}{4}$$

Volume Bottom :

$$V_{BOTTOM} = \frac{\pi * D^2}{4} H_h$$

Volume Head :

$$V_{HEAD} = \frac{\pi * D^2}{4} H_h \qquad H_h = \left(\frac{1}{6}\right) * D$$

Volume Reaktor:

$$V_R = V_{SHELL} + V_{BOTTOM} + V_{HEAD}$$

$$V_R = \frac{\pi * D^3}{4} + 2\left[\frac{\pi * D^2}{4} * \frac{D}{6}\right]$$

Dari penjabaran rumus diatas, Sehingga diperoleh :

$$\boxed{D = \sqrt[3]{\frac{12 * V_R}{4 * \pi}}} \qquad H_{Total} = H_S + (2 * H_h)$$

D=	3.8179 m
Hs=	3.8179 m
Hh=	0.6363 m
Htotal=	5.0905 m

Hs = D = 3,8179 m

Tekanan Desain

Volume tangki : 58.2767 m^3

Volume cairan : 48.5639 m^3

Tinggi tangki : 3,8179 m

Tinggi cairan dalam tangki = $\frac{Volume\ cairan}{volume\ tangki} * Hs$

Tinggi cairan dalam tangki = 3.1816 m

$$TekananHidrostatis = \rho * g * TinggiCairanDalamTangki$$

Diketahui :

ρ = 1030.8139 kg/m^3

g = 9,8 m/detik^2

2.5 atm = 253,3125 kPa

Tekanan hidrostatis = (1030.8139 kg/m^3 * 9,8 m/detik^2 * 3,1816 m)/1000

= 32.14 kPa

P operasi = Tekanan Hidrostatis + Tekanan pada reaktor

= 32,14 kPa + 253,3125 kPa

= 285.45 kPa

Tekanan Over Desain (20%)

Maka, P desain = 1,2 * 285,45 kPa

= 342.54 kPa = 49,68 psia

Tebal Shell Tangki

Dipilih : Bahan konstruksi carbon steel SA-285 Grade C

Spesifikasi : Max.Allowable Stress, f = 13750 psia

Efisiensi sambungan, E = 0.85

Corrosion Allowance, C = 0,002 in/tahun

Tekanan desain p = 49,68 psia

Jari-jari reaktor ri = 1.9089m

Umur alat Rencana n = 15 tahun

Tebal Dinding Silinder

$$t = \frac{p * ri}{f * E - 0.6 * p} + nC$$ (Lloyd E. Brownell and Edwin H. Young, 1959)

Maka :

ts = 0.0089 m

= 0.3535 in

Tebal Dinding Head (Tutup Tangki)

Dipilih : Bahan konstruksi carbon steel SA-285 Grade C

Spesifikasi : Max.Allowable Stress, f = 13750 psia

Efisiensi sambungan, E = 0.85

Corrosion Allowance, C = 0,002 in/tahun

Tekanan desain p = 49,68 psia

Diameter reaktor d = 3,8179 m

Umur alat Rencana n = 15 tahun

Tebal Dinding Head

$$t = \frac{p * d}{2 f * E - 0.2 p} + nC$$ (Lloyd E. Brownell and Edwin H. Young, 1959)

Maka :

th = 0.0089 m

= 0.3528 in

Perancangan Pengaduk

Komponen	BM (kg.kmol)	Rho (kg/m3)	Umpan			Xi(%)	μ (cp) wiki (2014)	ln μi	xi . ln μi	xi ρ
			Fm (kmol/jam)	Fw (kg/jam)	Fv (m3/jam)					
C8H9NO	135,1656	1120.00	0.0000	0.0000	0.0000	0.0000	4.4230	1.4868	0.0000	0.0000
C6H5NH2	93,1283	1020.00	26.6321	2480.2023	2.4316	0.2663	1.2200	0.1989	0.0530	271.6359
CH3COOH	60,0526	1050.00	28.3086	1700.0033	1.6191	0.2831	0.5200	-0.6539	-0.1851	297.2277
H20	18,0153	1000.00	45.0635	811.8321	0.8118	0.4506	0.4670	-0.7614	-0.3431	450.6163
		4190.00	100.0042	4992.0378	4.8625	1.0000	6.6300	0.2703	-0.4753	1019.4799

ln μ = Σxi ln μi = -0.4752

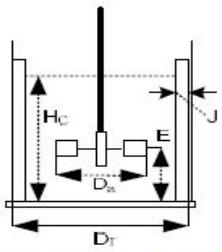
μ = 0.6217 cp = 0.0004 b/ft.s

ρ = 1030.8139 kg/m3 = 63.6441 lb/ft3

Jenis Pengadukan : Flat Six-Blade Turbine

Jumlah blade : 6

Jumlah buffle : 4



Gambar LC.14 Ukuran Turbin Untuk Reaktor

Dimana :

Hc = Tinggi cairan di dalam tangki (ft)
Da = Diameter pengaduk (ft)
Dt = Diameter tangki (ft)
J = Lebar *buffle* (ft)
E = Tinggi daun pengaduk dari dasar tangki (ft)

W = Lebar Blade pengadukan (ft)

L = Panjang Blade pengaduk (ft)

Data Pengadukan Standar :

$$Da = \frac{1}{3} * Dt \qquad E = 1 * Da \qquad L = \frac{1}{4} * Da$$

Diketahui :

Da = (1/3)* 3.8179 m = 1.2726 m = 4.1753 ft

E = 1*4.1753 ft = 4.1753 ft

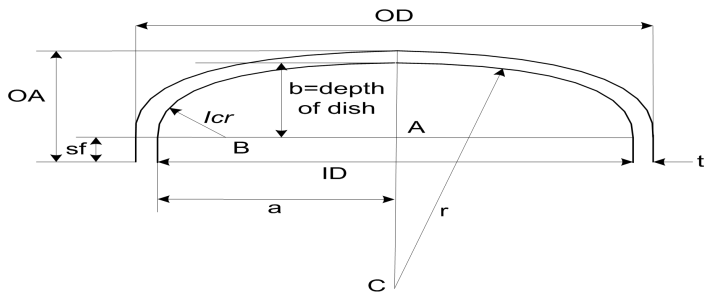
L = (1/4)* 4.1753 m = 1.0438 m

Data Pengadukan jenis *Flat-six-blade turbine*

$$W = \frac{1}{5} D_a \qquad J = \frac{1}{12} * Dt$$

W = (1/5)* 1.2726 m = 0.8351 m

J = (1/12)* 3.8179 m = 0.3182 m



Bilangan Reynold (Nre)

$$Nre = \frac{n * Da^2 * \rho}{\mu}$$

Diketahui :

Nre = (1,5 putaran/s * (4.1753 ft)^2 * 63.6441 lb/ft3) / 0.0004 lb/ft.s

Nre = 4027.89164

Daya Pengadukan :

$$P = \frac{Kt * n^3 * Da^5 \rho}{gc}$$

ρ = 1030.8139 kg/m3 = 63.6441 lb/ft3

μ = 0.0004 lb/ft.s

gc = 9,805416 m/s

Np = Kt = 5,75

(Unit Operations of Chemical Engineering, Mc Cabe)

Maka :

P = 6810.1943 J/s = 9.132619543 Hp

Efisiensi = 0,85

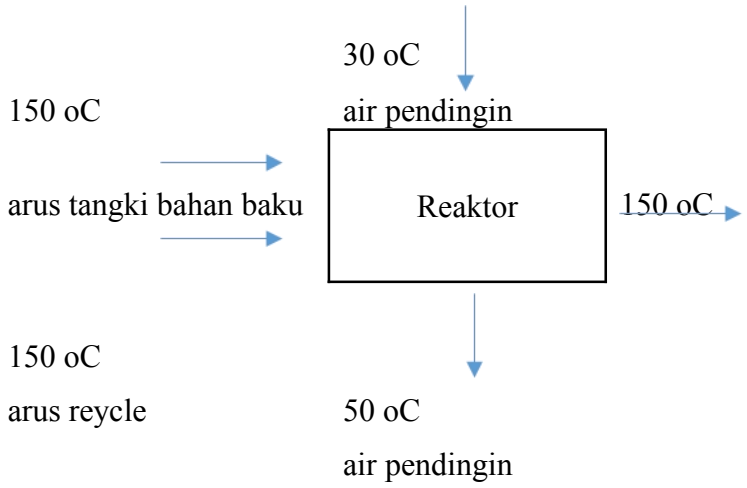
Daya motor penggerak = 0,85 * 9.132619543 Hp

= 11.4157 Hp

Perhitungan Neraca Panas

Perhitungan Panas Reaksi di R-01

Asumsi : Reaksi berlangsung isothermal pada suhu 120 ^oC



Panas masuk reaktor = Panas keluar heater anilin + Panas keluar heater asam asetat

= 676177,2753 kJ/jam + 522135,98094 kJ/jam

= 1198313,0847 kJ/jam

Perhitungan Panas Reaksi Standar

Data panas pembentukan standar

Komponen	Δ Hf
C8H9NO	-78,4852
H2O	-57,8
C6H5NH2	20,76
CH3COOH	-103,93

Panas reaksi standar pada suhu 25 oC dicari dengan persamaan berikut :

$$\Delta Hf^{o} = (\Delta Hf^{o}_{asetanilida} + \Delta Hf^{o}_{air}) - (\Delta Hf^{o}_{anilin} + \Delta Hf^{o}_{asamaseta})$$

ΔHf0 = -53.1152 kkal/kmol

ΔHf0 = -222233.9968 kJ/kmol

Panas keluar reaktor

Komponen	N^{-1} senyawa (kmol/jam)	∫ cpl dT	N-1 ∫ cpl dT
C8H9NO	19.0636	21096.9500	402184.0281
H2O	62.2460	9472.4497	589622.3595
C6H5NH2	9.4496	22297.6154	210703.5467
CH3COOH	11.1261	12895.4567	143476.0792
Total	101.8853	65762.4718	1345986.0135

Panas reaksi pada suhu reaktor :

Suhu operasi reaktor : T = 150 ^oC = 423 K

$$\Delta Hr_{423}{}^{o} = \Delta Hr^{o} - \int_{298}^{423} Cp_{anilin}\,dT - \int_{298}^{423} Cp_{asamasetat}\,dT + \int_{298}^{423} Cp_{asetanilida}\,dT + \int_{298}^{423} Cp_{air}\,dT$$

$\Delta Hr_{423}{}^{0}$ = -226857.6693 kJ/kmol

Panas reaksi total = N senyawa C8H9NO x ΔHr

= 19.0636 kmol/jam x (-226857.6693 kJ/kmol)

= -4324726.1444 kJ/jam

Q = (Qout – Q in) + Panas reaksi total

Q = -3921145.1217 kJ.jam

	Arus in (kJ.jam)	Arus Out (kJ/jam)
Umpan	942404.9908	-
Produk	-	1345986.0135
r x ΔHr	-	-4324726.1444
Air Pendingin	985244.4147	4906389.5364
Total	1927649.4055	1927649.4055

F. Perancangan Jaket Pendingin

Medium Pendingin

Dipilih : Air pada suhu 30 oC dan tekanan 1 atm

Tc1 = Suhu air masuk jaket = 30 ^oC = 86 ^oF

Tc2 = Suhu air keluar jaket = 50 ^oC = 122 ^oF

Tc,avg = suhu air rata-rata = 1/2 (Tc1 + Tc2)

= 40 ^oC = 104 ^oF

= 313.2 K

Diperoleh : wc = 2659,8600 kg/jam

$V_{air\ pendingin}$ = $\frac{2659,8600}{1000}$

= 2,6599 m^3/jam

Diameter dalam jaket (D_1) = diameter dalam + (2 x tebal dinding)

= 3.8356 m = 151.0097 in

Tinggi jaket = 4.4542 m

Asumsi jarak jaket = 5 in = 0,127 m

Diameter luar jaket (D_2) = D_1 + (2x jarak jaket)

= 4.0897 m = 161.0100 in

Luas yang dilalui air pendingin (A)

$$A = \frac{\pi}{4}\left(D_2^2 - D_1^2\right)$$

A = 2449.3575 in^2

= 1.5802 m^2

Kecepatan air pendingin (v)

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

= 1.6832 m /jam

Tebal dinding jaket

Bahan Carbon Steel Plate SA-285 grade C

H jaket = 4.4542 m = 14.6134 ft

$$Phidrostatis = \frac{H-1}{144} * \rho air$$

$P_{hidrostatis}$ = 5.8963 psia

Pdesain = Pdesain reaktor + Phidrostatis

= 55.5779 psia

allowable strees (f)	:	13750	psia
welded joint (E)	:	0.85	
Corossion allowance (C)	:	0,002	in/tahun
umur alat (n)	:	15	tahun

$$tj = \frac{PD}{SE - 0{,}6P} + n.\,C$$

tj = 0.7456 in

dipilih tebal jaket standar = 1 in (Tabel 5.2 Brownel & Young)

PERANCANGAN REAKTOR 2

Dimensi Reaktor

Diameter dan Tinggi Reaktor Menurut Peters dan Timmerhaus (1980), overdesign yang direkomendasikan untuk "Continuous Reactor" adalah 20 %. Jadi volume masing-masing reaktor adalah :

Fv = 5,0895 m^3/jam

t = 9,8 jam

V1 = V2 = 48.5639 m^3

V_R = 1.2 Vi = 58.2767 m^3

Spesifikasi Reaktor :

$$V_R = V_{SHELL} + V_{BOTTOM} + V_{HEAD}$$

Dirancang : D = H

Perbandingan tinggi tangki dengan diameter tangki (Hs : D) = 1 : 1

Volume Shell :

$$V_{SHELL} = \frac{\pi * D^2}{4} * H_S$$

$$V_{SHELL} = \frac{\pi * D^3}{4}$$

Volume Bottom :

$$V_{BOTTOM} = \frac{\pi * D^2}{4} H_h$$

Volume Head :

$$V_{HEAD} = \frac{\pi * D^2}{4} H_h \qquad H_h = \left(\frac{1}{6}\right) * D$$

Volume Reaktor:

$$V_R = V_{SHELL} + V_{BOTTOM} + V_{HEAD}$$

$$V_R = \frac{\pi * D^3}{4} + 2\left[\frac{\pi * D^2}{4} * \frac{D}{6}\right]$$

Dari penjabaran rumus diatas, Sehingga diperoleh :

$$\boxed{D = \sqrt[3]{\frac{12 * V_R}{4 * \pi}}} \qquad H_{Total} = H_S + (2 * H_h)$$

D=	3.8179 m
Hs=	3.8179 m
Hh=	0.6363 m
Htotal=	5.0905 m

Hs = D = 3,8179 m

Tekanan Desain

Volume tangki : 58.2767 m^3

Volume cairan : 48.5639 m^3

Tinggi tangki : 3,8179 m

Tinggi cairan dalam tangki = $\frac{Volume\ cairan}{volume\ tangki} * Hs$

Tinggi cairan dalam tangki = 3.1816 m

$$TekananHidrostatis = \rho * g * TinggiCairanDalamTangki$$

Diketahui :

ρ = 1030.8139 kg/m^3

g = 9,8 m/detik^2

2.5 atm = 253,3125 kPa

Tekanan hidrostatis = (1030.8139 kg/m^3 * 9,8 m/detik^2 * 3,1816 m)/1000

= 32.14 kPa

P operasi = Tekanan Hidrostatis + Tekanan pada reaktor

= 32,14 kPa + 253,3125 kPa

= 285.45 kPa

Tekanan Over Desain (20%)

Maka, P desain = 1,2 * 285,45 kPa

= 342.54 kPa = 49,68 psia

Tebal Shell Tangki

Dipilih : Bahan konstruksi carbon steel SA-285 Grade C

Spesifikasi : Max.Allowable Stress, f = 13750 psia

Efisiensi sambungan, E = 0.85

Corrosion Allowance, C = 0,002 in/tahun

Tekanan desain p = 49,68 psia

Jari-jari reaktor ri = 1.9089m

Umur alat Rencana n = 15 tahun

Tebal Dinding Silinder

$$t = \frac{p * ri}{f * E - 0.6 * p} + nC$$ (Lloyd E. Brownell and Edwin H. Young, 1959)

Maka :

ts = 0.0089 m

= 0.3535 in

Tebal Dinding Head (Tutup Tangki)

Dipilih : Bahan konstruksi carbon steel SA-285 Grade C

Spesifikasi : Max.Allowable Stress, f = 13750 psia

Efisiensi sambungan, E = 0.85

Corrosion Allowance, C = 0,002 in/tahun

Tekanan desain p = 49,68 psia

Diameter reaktor d = 3,8179 m

Umur alat Rencana n = 15 tahun

Tebal Dinding Head

$$t = \frac{p * d}{2 f * E - 0.2 p} + nC$$ (Lloyd E. Brownell and Edwin H. Young, 1959)

Maka :

th = 0.0089 m

= 0.3528 in

Perancangan Pengaduk

Komponen	BM (kg.kmol)	Rho (kg/m3)	Umpan			Xi(%)	μ (cp) wiki (2014)	ln μi	xi . ln μi	xi ρ
			Fm (kmol/jam)	Fw (kg/jam)	Fv (m3/jam)					
C8H9NO	135.1656	1120.0000	19.0636	2576.7443	2.3007	0.1871	4.4230	1.4868	0.2782	209.5615
C6H5NH2	93.1283	1020.0000	9.4496	880.0254	0.8628	0.0927	1.2200	0.1989	0.0184	94.6024
CH3COOH	60.0526	1050.0000	11.1261	668.1505	0.6363	0.1092	0.5200	-0.6539	-0.0714	114.6622
H20	18.0153	1000.0000	62.2460	1121.3796	1.1214	0.6109	0.4670	-0.7614	-0.4652	610.9420
		4190.0000	101.8853	5246.2998	4.9211	1.0000	6.6300	0.2703	-0.2400	1029.7681

ln μ = Σxi ln μi = -0.4752

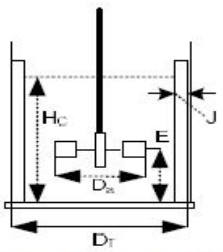
μ = 0.6217 cp = 0.0004 b/ft.s

ρ = 1030.8139 kg/m3 = 63.6441 lb/ft3

Jenis Pengadukan : Flat Six-Blade Turbine

Jumlah blade : 6

Jumlah buffle : 4



Gambar LC.14 Ukuran Turbin Untuk Reaktor

Dimana :

Hc = Tinggi cairan di dalam tangki (ft)
Da = Diameter pengaduk (ft)
Dt = Diameter tangki (ft)
J = Lebar *buffle* (ft)
E = Tinggi daun pengaduk dari dasar tangki (ft)

W = Lebar Blade pengadukan (ft)

L = Panjang Blade pengaduk (ft)

Data Pengadukan Standar :

$$Da = \frac{1}{3} * Dt \qquad E = 1 * Da \qquad L = \frac{1}{4} * Da$$

Diketahui :

Da = (1/3)* 3.8179 m = 1.2726 m = 4.1753 ft

E = 1*4.1753 ft = 4.1753 ft

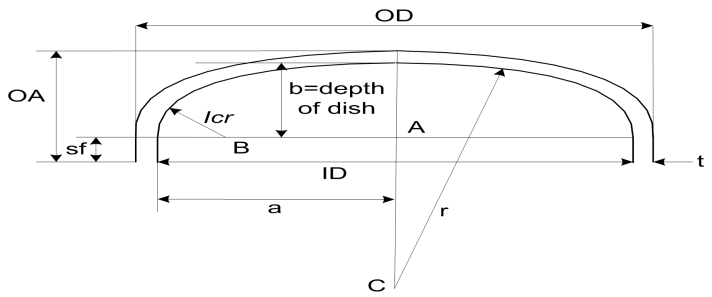
L = (1/4)* 4.1753 m = 1.0438 m

Data Pengadukan jenis *Flat-six-blade turbine*

$$W = \frac{1}{5} D_a \qquad J = \frac{1}{12} * Dt$$

W = (1/5)* 1.2726 m = 0.8351 m

J = (1/12)* 3.8179 m = 0.3182 m



Bilangan Reynold (Nre)

$$Nre = \frac{n * Da^2 * \rho}{\mu}$$

Diketahui :

Nre = (1,5 putaran/s * (4.1753 ft)^2 * 63.6441 lb/ft3) / 0.0004 lb/ft.s

Nre = 4027.89164

Daya Pengadukan :

$$P = \frac{Kt * n^3 * Da^5 \rho}{gc}$$

ρ = 1030.8139 kg/m3 = 63.6441 lb/ft3

μ = 0.0004 lb/ft.s

gc = 9,805416 m/s

Np = Kt = 5,75

(Unit Operations of Chemical Engineering, Mc Cabe)

Maka :

P = 6810.1943 J/s = 9.132619543 Hp

Efisiensi = 0,85

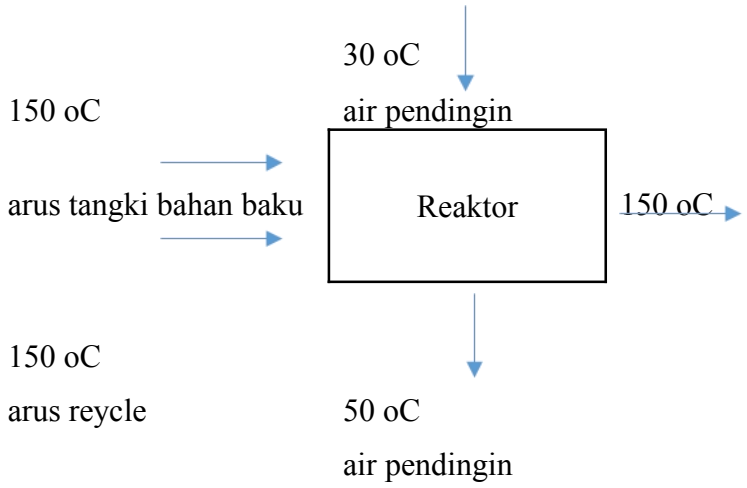
Daya motor penggerak = 0,85 * 9.132619543 Hp

= 11.4157 Hp

Perhitungan Neraca Panas

Perhitungan Panas Reaksi di R-01

Asumsi : Reaksi berlangsung isothermal pada suhu 120 ^oC



Panas masuk reaktor = Panas keluar heater anilin + Panas keluar heater asam asetat

= 676177,2753 kJ/jam + 522135,98094 kJ/jam

= 1198313,0847 kJ/jam

Perhitungan Panas Reaksi Standar

Data panas pembentukan standar

Komponen	Δ Hf
C8H9NO	-78,4852
H2O	-57,8
C6H5NH2	20,76
CH3COOH	-103,93

Panas reaksi standar pada suhu 25 oC dicari dengan persamaan berikut :

$$\Delta Hf^{o} = (\Delta Hf^{o}_{asetanilida} + \Delta Hf^{o}_{air}) - (\Delta Hf^{o}_{anilin} + \Delta Hf^{o}_{asamaseta})$$

ΔHf0 = -53.1152 kkal/kmol

ΔHf0 = -222233.9968 kJ/kmol

Panas keluar reaktor

Komponen	N-1 senyawa (kmol/jam)	∫ cpl dT	N-1 ∫ cpl dT
C8H9NO	27.0958	21096.9500	571638.1064
H2O	70.2782	9472.4497	665706.5909
C6H5NH2	1.4174	22297.6154	31605.5320
CH3COOH	3.0939	12895.4567	39897.7072
Total	101.8853	65762.4718	1308847.9365

Panas reaksi pada suhu reaktor :

Suhu operasi reaktor : T = 150 ^{o}C = 423 K

$$\Delta Hr_{423}{}^{o} = \Delta Hr^{o} - \int_{298}^{423} Cp_{anilin}\,dT - \int_{298}^{423} Cp_{asamasetat}\,dT + \int_{298}^{423} Cp_{asetanilida}\,dT + \int_{298}^{423} Cp_{air}\,dT$$

$\Delta Hr_{423}{}^{0}$ = -226857.6693 kJ/kmol

Panas reaksi total = N senyawa C8H9NO x ΔHr

= 27.0958 kmol/jam x (-226857.6693 kJ/kmol)

= -6146883.2444kJ/jam

Q = (Qout – Q in) + Panas reaksi total

Q = -6184021.3214 kJ.jam

	Arus in (kJ.jam)	Arus Out (kJ/jam)
Umpan	1345986.0135	-
Produk	-	1308847.9365
r x ΔHr	-	-6146883.2444
Air Pendingin	1553824.7828	7737846.1042
Total	2899810.7963	2899810.7963

F. Perancangan Jaket Pendingin

Medium Pendingin

Dipilih : Air pada suhu 30 oC dan tekanan 1 atm

Tc1 = Suhu air masuk jaket = 30 ^{o}C = 86 ^{o}F

Tc2 = Suhu air keluar jaket = 50 ^{o}C = 122 ^{o}F

Tc,avg = suhu air rata-rata = 1/2 (Tc1 + Tc2)

= 40 ^{o}C = 104 ^{o}F

= 313.2 K

Diperoleh : wc = 2659,8600 kg/jam

$V_{air\ pendingin}$ = $\frac{2659,8600}{1000}$

= 2,6599 m^3/jam

Diameter dalam jaket (D_1) = diameter dalam + (2 x tebal dinding)

= 3.8356 m = 151.0097 in

Tinggi jaket = 4.4542 m

Asumsi jarak jaket = 5 in = 0,127 m

Diameter luar jaket (D_2) = D_1 + (2x jarak jaket)

= 4.0897 m = 161.0100 in

Luas yang dilalui air pendingin (A)

$$A = \frac{\pi}{4}\left(D_2^2 - D_1^2\right)$$

A = 2449.3575 in^2

= 1.5802 m^2

Kecepatan air pendingin (v)

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

= 1.6832 m /jam

Tebal dinding jaket

Bahan Carbon Steel Plate SA-285 grade C

H jaket = 4.4542 m = 14.6134 ft

$$Phidrostatis = \frac{H-1}{144} * \rho air$$

$P_{hidrostatis}$ = 5.8963 psia

Pdesain = Pdesain reaktor + Phidrostatis

= 55.5779 psia

allowable strees (f)	:	13750	psia
welded joint (E)	:	0.85	
Corossion allowance (C)	:	0,002	in/tahun
umur alat (n)	:	15	tahun

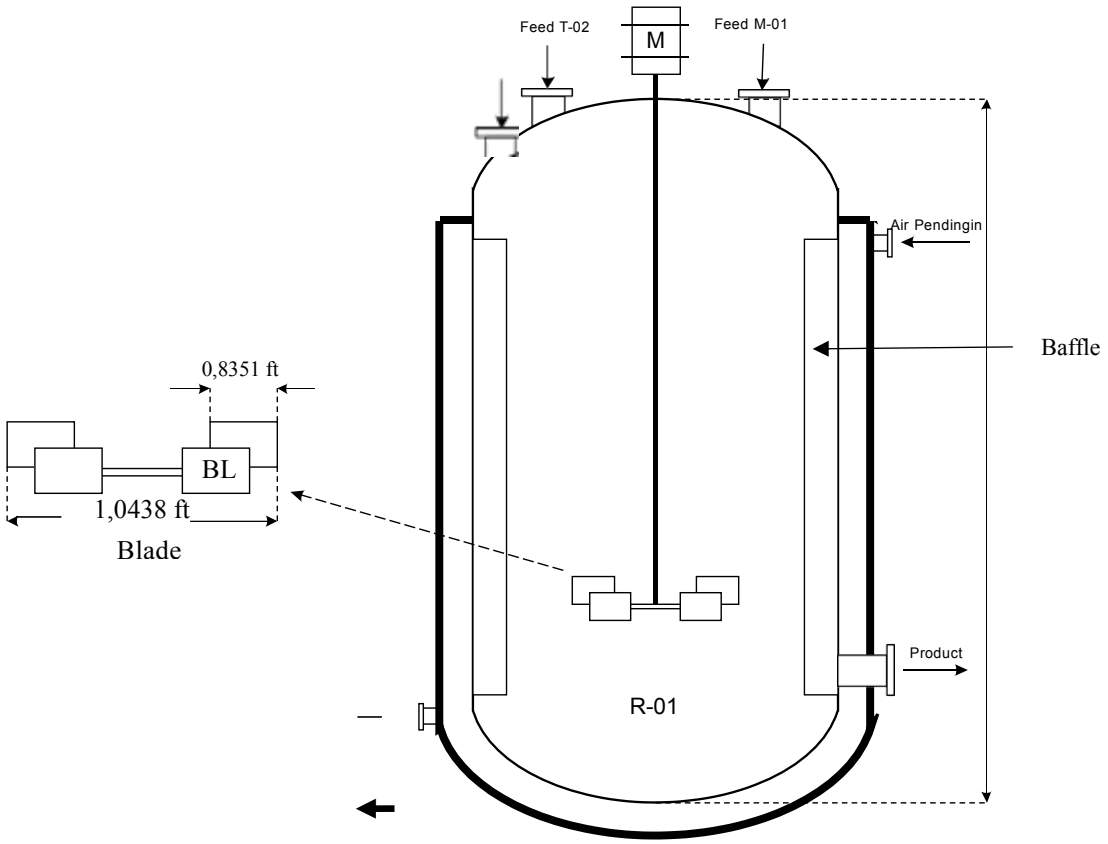
$$tj = \frac{PD}{SE - 0{,}6P} + n.\,C$$

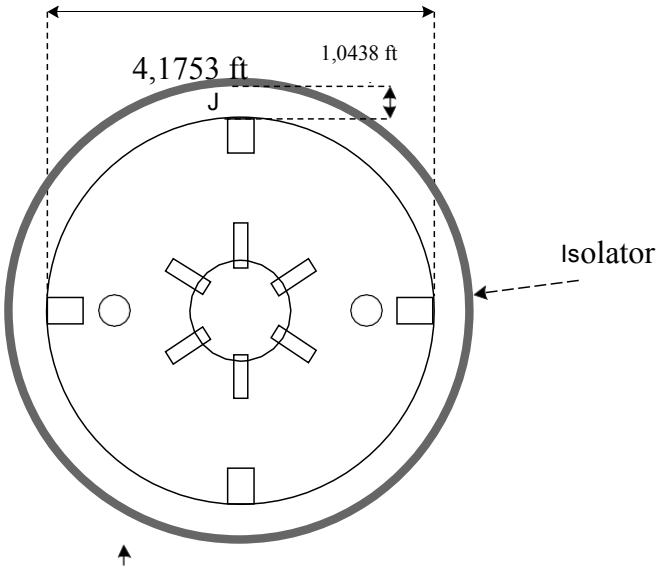
tj = 0.7456 in

dipilih tebal jaket standar = 1 in (Tabel 5.2 Brownel & Young)

LAMPIRAN B

GAMBAR REAKTOR



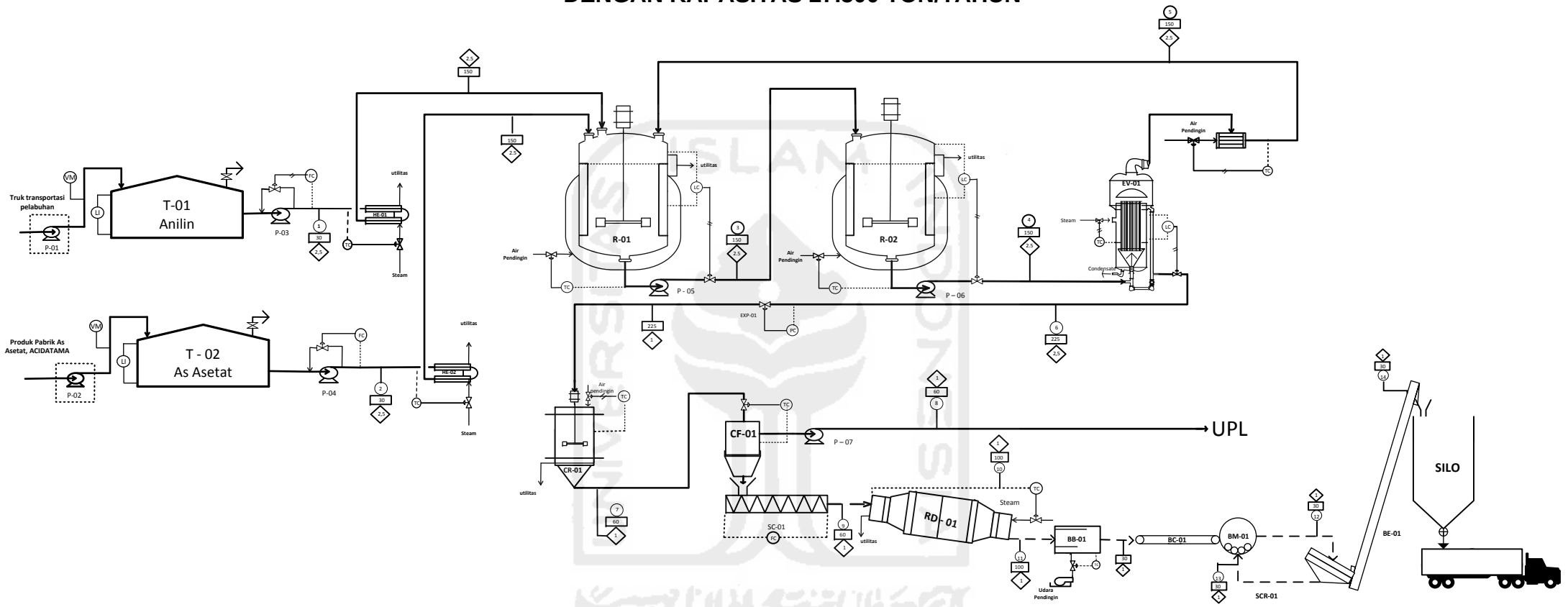


Keterangan :

BL = Blade
J = Jaket
R = Reaktor
M = Motor Penggerak
P = Pengaduk

PROCESS ENGINEERING FLOW DIAGRAM

PRA RANCANGAN PABRIK ASETANILIDA DARI ANILIN DAN ASAM ASETAT DENGAN KAPASITAS 27.500 TON/TAHUN



NOMOR	Komponen	NOMOR ARUS (kg/jam)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	C6H5NHCOCH3 (s)							3408,1553		3408,1553		3408,1553	3587,5319	179,3766	3408,1553
2	C6H5NHCOCH3 (l)			2576,7443	3662,4160	254,1420	3408,2740	0,1187	0,1187						
3	C6H5NH2		2401,0000	880,0254	132,0038	79,2023	52,8015	52,8015	26,4008	26,4008		26,4008	27,7903	1,3895	26,4008
4	CH3COOH	1588,5241		668,1505	185,7987	111,4792	74,3195	74,3195	37,1597	37,1597		37,1597	39,1155	1,9558	37,1597
5	H2O	3,1834	49,0000	1121,3796	1266,0812	759,6487	506,4325	506,4325	253,2162	253,2162	252,7098	0,5064	0,5331	0,0267	0,5331
Jumlah :		1591,7075	2450,0000	5246,2998	5246,2998	1204,4723	4041,8275	4041,8275	316,8954	3724,9321	252,7098	3472.2222	3654,9708	182,7485	3472.2222

Keterangan :

BB	Blower Box	S	Silo
BC	Belt conveyor	T	Tangki
BE	Bucet elevator	CD	Condensor
CF	Centrifuge	TC	Temperature Controller
CR	Cristalyzer	SC	Screw Conveyor
EV	Evaporator	○	Nomer Arus
FC	Flow Controller	□	Suhu, C
HE	Heater	◇	Tekanan , atm
LC	Level Controller	-/-	Sinyal Pneumatic
LI	Level Indicator	----	Sinyal Electric
P	Pompa	—	Piping
RD	Rotary Dryer		
R	Reaktor		

JURUSAN TEKNIK KIMIA
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YOGYAKARTA
2016

PROCESS ENGINEERING FLOW DIAGRAM
PABRIK ASETANILIDA DARI ANILIN DAN ASAM ASETAT
KAPASITAS 27.5000 TON/TAHUN

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