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_5 $NHCOCH_3$ = 99,7 %

Konversi reaksi 85 %

Sifat Komponen yang Terlibat

Komponen	**BM**
CH_3COOH	60.0526
C_6H_5NH2	93.1283
C_6H_5 $NHCOCH_3$	135.1656
H2O	18.0153

A. Kinetika Reaksi

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

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

Persamaan Laju Reaksi

Reaksi dianggap berorder 1 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 = 10,10 menit

Menghitung konsentrasi awal a (Ca0) :

komponen	BM (kg/kmol)	rho(kg/m3)	Fm (kmol/jam)	Fw (kg/jam)	Fv (m3/jam)	%mol
asetanilida	135,1600	1022,00	0,0000	2,7084	0,0027	0,0000
anilin	93,1300	1210,00	14,0830	1311,5486	1,0839	0,3319
asam asetat	60,0500	1022,00	28,1660	1691,3668	1,6550	0,6637
air	18,0200	995,60	0,1877	29,6137	0,0297	0,0044
		4249,60	42,4367	3035,2374	2,7713	1,0000

$$Ca0 = \frac{Fm}{Fv_{total}}$$

Sehingga : Ca0 = 5,0818 kmol/m^3

Cb0 = 10,1635 kmol/m^3

M = Cb0/Ca0 = 2,0000

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 = 0,0759 kmol/m3.jam

B. Perancangan Reaktor

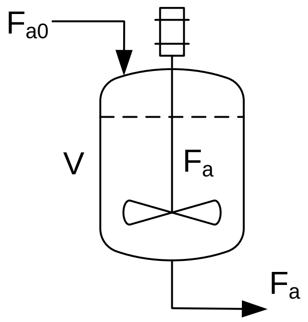
Model Matematis Perancangan Reaktor

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 = 2,7713 m^3/jam

Ca0 = 5,0818 kmol/m^3

M = Cb0/Ca0 = 2,0000

Xa = 0,85

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

= 0,1086 m^3/kmol.jam

Sehingga diperoleh :

V = 24,7451 m^3

t = 8,92 jam

Menetukan optimasi jumlah reaktor

1. Jumlah Reaktor = 1

X_{A1} = 0,85

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

Fv = 2,7713 m^3/jam

Ca0 = 5,0818 kmol/m^3

Persamaan Umum

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

$V_{coba\text{-}coba}$ = 29,7451 m^3 = 7857,8237 gal

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

$= 0,85 - \dfrac{29,7451 \; .0,1086 \; .5,0818(1-0,85)(2,0000-0,85)}{2,7713}$

= 0,7167

t = 10,73

2. Jumlah Reaktor = 2

X_{A1} = 0,85

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

Fv = 2,7713 m^3/jam

Ca0 = 5,0818 kmol/m^3

Persamaan Umum

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

$V_{coba\text{-}coba}$ = 15,7421 m^3 = 4158,6227 gal

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

$= 0,85 - \dfrac{15,7421 \; .0,1086 \; .5,0818(1-0,85)(2,0000-0,85)}{2,7713}$

= 0,3092

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

$$= 0{,}3092 - \frac{15{,}7421 \; .0{,}1086 \, .5{,}0818(1 - 0{,}3092)(2{,}0000 - 0{,}3092)}{2{,}7713}$$

= 0

t = 5,08

3. Jumlah Reaktor = 3

X_{A1} = 0,85

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

Fv = 2,7713 m^3/jam

Ca0 = 5,0818 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

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

$$= 0{,}85 - \frac{24{,}2793 \; .0{,}1086 \, .5{,}0818(1 - 0{,}85)(2{,}0000 - 0{,}85)}{2{,}7713}$$

= 0,0160

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

$$= 0{,}00160 - \frac{24{,}2793 \; .0{,}1086 \, .5{,}0818(1 - 0{,}7445)(2{,}0000 - 0{,}7445)}{2{,}7713}$$

= 0

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

$$= -9{,}4240 - \frac{24{,}2793\ .0{,}1086\ .5{,}0818(1 - -9{,}4240)(2{,}0000 - -9{,}4240)}{2{,}7713}$$

= 0

4. Jumlah Reaktor = 4

X_{A1} = 0,85

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

Fv = 2,2213m^3/jam

Ca0 = 5,0818 kmol/m^3

Persamaan Umum

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

$V_{coba\text{-}coba}$ = 16,,7910 m^3 = 4171,4507gal

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

$$= 0{,}85 - \frac{15{,}7910\ .0{,}1086\ .5{,}0818(1 - 0{,}85)(2{,}0000 - 0{,}85)}{2{,}7713}$$

= 0,3076

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

$$= 0{,}3076 - \frac{16{,}7910\ .0{,}1086\ .5{,}0818(1 - 0{,}3076)(2{,}0000 - 0{,}3076)}{2{,}7713}$$

= 0

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

$$= -3{,}3779 - \frac{15{,}7910\ .0{,}1086\ .5{,}0818(1 - -3{,}3780)(2{,}0000 - -3{,}3780)}{2{,}7713}$$

= 0

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

$$=-77{,}4138- \frac{15{,}7910 \quad .0{,}1086\,.2{,}0000(1--77{,}4137)(2{,}0000--77{,}4137)}{2{,}7713}$$

= 0

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

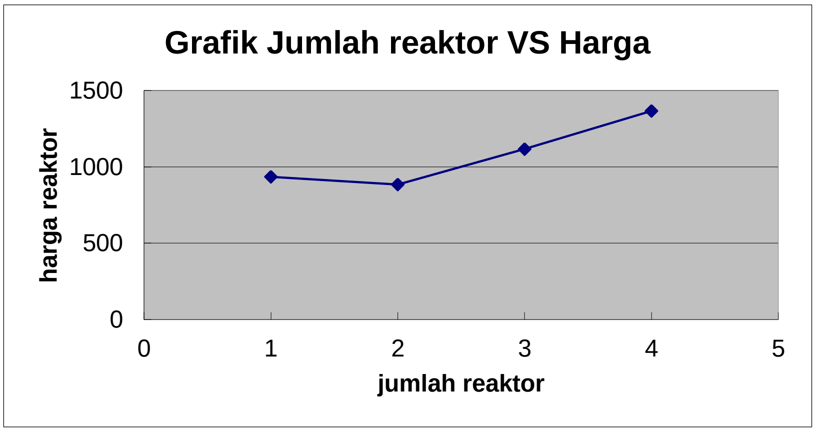
H = n. K. $V^{0,6}$; Karena K = Konstanta, maka

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	7857,8237	7857,8237	217,3609	217,3609
2	4158,6227	8317,2453	224,8991	449,7982
3	6413,9122	19241,7366	372,0031	1116,0093
4	4171,5407	16686,1627	341,5182	1366,0729



Grafik Hubungan Jumlah reakor dan harga reakor ($)

Menghitung Neraca Massa Tiap Reaktor

Reaktor I

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

No. Arus	3		
Total flowrate	3002,9153	kg/h	
komponen	%massa	kg/h	kmol/h
asetanilida (l)	0,3317	1893,9393	14,0126
asetanilida (s)	0,0000	0,0000	0,0000
air	0,3317	252,5066	14,0126
aniline	0,0017	6,5577	0,0704
asam asetat	0,3350	849,9118	14,1534
total	1,0000	3002,9153	42,2490

Reaktor II

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

No. Arus	3		
Total flowrate	3002,9153	kg/h	
Komponen	%mol	kg/h	kmol/h
asetanilida (l)	0,3302	1893,9393	14,0120
asetanilida (s)	0,0000	0,0000	0,0000
air	0,3303	252,5066	14,0162
aniline	0,0017	6,5577	0,0704
asam asetat	0,3335	849,9118	14,1528
total	1,0000	3002,9153	42,2514

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 = 2,7713 m^3/jam

t = 10,10 jam

V1 = V2 = 28,0016 m^3

V_R = 1.2 Vi = 33,6019 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 :

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

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 :

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

D =	3,1777m
Hs =	3,1777 m
Hh =	0,5298 m
Htotal =	4,2369 m

Hs = D = 3,1777 m

Tekanan Desain

Volume tangki : 33,6019 m^3

Volume cairan : 28,0016 m^3

Tinggi tangki : 3,1777 m

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

Tinggi cairan dalam tangki = 2,6481m

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

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/$detik^2$ * 2,6481 m)/100

= 26,75 kPa

P operasi = Tekanan Hidrostatis + Tekanan pada reaktor

= 26,75 kPa + 253,3125 kPa

= 280,06kPa

Tekanan Over Desain (20%)

Maka, P desain = 1,2 * 280,06kPa

= 336,08 kPa = 48,74 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 = 0,0020 in/tahun
	Tekanan desain	p = 48,74psia

Jari-jari reaktor ri = 1,5888 m

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 = 0,0078 m

= 0,3101 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 = 0.8

Corrosion Allowance, C = 0,0020 in/tahun

Tekanan desain p = 48,74 psia

Diameter reaktor d = 3,1777 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 = 0,0078 m

= 0,3107in

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	1022,00	0,0000	0,0000	0,0000	0,0000	4,4230	1,486818199	0,0000	0,0000
C6H5NH2	93,1283	1210,00	0,0704	6,5577	0,0054	0,0025	1,2200	0,198850859	0,0005	3,0175
CH3COOH	60,0526	1022,00	14,1534	849,9118	0,8316	0,5012	,5200	-0,653926467	-0,3278	512,2743
H20	18,0153	995,60	14,0126	252,5066	0,2536	0,4963	,4670	-0,761426021	-0,3779	494,0758
		4249,60	28,2364	1108,9761	1,0907	1,0000	6,6300	0,270316569	-0,7051	1009,3676
				m/jam	0,0011					

$\ln \mu = \Sigma x_i \ln \mu_i = -0,3178$

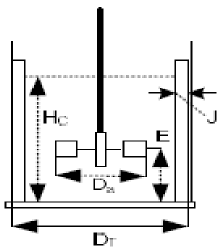
$\mu = 0,4940$ cp $= 0,0003$ lb/ft.s

$\rho = 1009,3676$ kg/m3 $= 63,0128$ 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 :

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

Diketahui :

Da = (1/3)* 3,1777 m = 1,0592m = 3,4752 ft

E = 1*3,4752 ft = 3,4752 ft

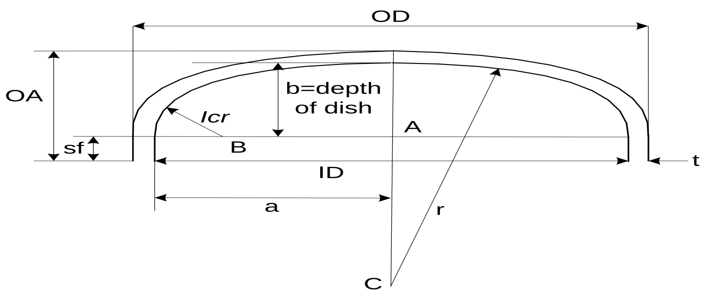
L = (1/4)* 3,4752 m = 0,8688 m

Data Pengadukan jenis *Flat-six-blade turbine*

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

W = (1/5)* 3,4752 m = 0,6950 m

J = (1/12)* 3,1777 m = 0,2648 m = 0,8688ft



Bilangan Reynold (Nre)

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

Diketahui :

Nre = (1,5 putaran/s * (1,0592 m)^2 * 1030,8139 kg/m3) / 0,4940 kg/m.s

Nre = 3511,5137

Daya Pengadukan :

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

ρ = 2720,2500 kg/m3

μ = 0,4940 kg/m.s

gc = 9,805416 m/s

Np = Kt = 5,75

(Unit Operations of Chemical Engineering, Mc Cabe)

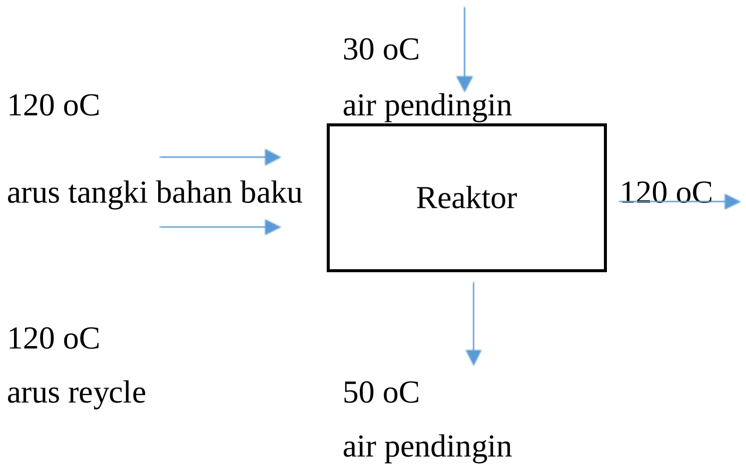
Maka :

P	= 2720,2500 J/s = 3,6479 Hp
Efisiensi	= 0,8
Daya motor penggerak	= 0,8 * 3,6479 Hp
	= 4,5598 Hp

Perhitungan Neraca Panas

Perhitungan Panas Reaksi di R-01

Asumsi : Reaksi berlangsung isothermal pada suhu 120 ^{o}C



Panas masuk reaktor = Panas keluar heater anilin + Panas keluar heater asam asetat + panas keluar heater R centrifige

= 237966,4 kJ/jam + 4618,934 kJ/jam + 173007,3

= 415592,5444 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 :

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

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	14,0126	14909,0720	208914,4473
H2O	15,6560	1949,9789	30528,7759
C6H5NH2	0,0704	11042,2008	777,5359
CH3COOH	14,0126	11927,1236	168809,3749
Total	43,8923	39828,3752	4090340,1340

Panas reaksi pada suhu reaktor :

Suhu operasi reaktor : T = 120 ^oC = 393 K

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

$\Delta Hr_{423}{}^{0}$ = - 226394,2914 kJ/kmol

Panas reaksi total = N senyawa C8H9NO x ΔHr

= 14,0126 kmol/jam x (- 226394,2914 kJ/kmol)

= - 3172366,345 kJ/jam

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

Q = 436354,3538- 415592,5444) + (- 3172366,345)

Q = - 3252604,345 kJ.jam

	arus in (kJ.jam)	Arus Out (kJ/jam)
Umpan	415592,5444	-
Produk	-	436354,3538
r x ΔHr	-	-3172366,345
Air Pendingin	-3151604,536	-
Total	-2736011,992	-2736011,992

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 = 1931,2083 kg/jam

$V_{air\ pendingin}$ = $\frac{1931,2083}{1000}$

= 1,9312 m^3/jam

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

= 3,1933 m + (2 x 0,0098 m)

= 3,1933 m = 125,721 in

Tinggi jaket = tinggi rekator

= 3,7073 m

Asumsi jarak jaket = 5 in = 0,127 m

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

= 3,1777 m + (2 x 0,0078 m)

= 135,7212 in = 3,4473 m

Luas yang dilalui air pendingin (A)

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

A = 2052,3234 in^2

= 1,3241 m^2

Kecepatan air pendingin (v)

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

= 1,4585 m /jam

Tebal dinding jaket

Bahan Carbon Steel Plate SA-285 grade C

H jaket = 3,7073 m = 12,1631 ft

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

$P_{hidrostatis}$ = 4,8350 psia

Pdesain = Pdesain reaktor + Phidrostatis

= 48,74 psia + 4,8350 psia

= 53,5787 psia

allowable strees (f)	:	13750	psia
welded joint (E)	:	0.8	
Corossion allowance (C)	:	0,0020	in/tahun
umur alat (n)	:	15	tahun

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

tj = 0,6401 in

dipilih tebal jaket standar = 0,6401 in (Tabel 5.2 Brownel & Young)