LAMPIRAN

PERANCANGAN REAKTOR (R-01)

Jenis : *Continuous Stirred Tank Reactor*

Fungsi : Tempat berlangsungnya reaksi antara Natrium Hidroksida dan Asam Nitrat

Kondisi Operasi :

- Suhu : 60°C
- Tekanan : 1 atm
- Konversi : 98%
- Waktu tinggal (θ) : 1 jam
- Reaksi yang terjadi di dalam reaktor :

$$NaOH + HNO_3 \longrightarrow NaNO_3 + H_2O$$

(U.S. Patent. 2,535,990)

A. Dasar Pemilihan Jenis Reaktor

Dipilih CSTR dengan pertimbangan sebagai berikut:

1. Fase umpan yang akan direaksikan adalah cair
2. Harga alat relatif lebih murah
3. Perawatan dan pembersihan alat lebih mudah
4. Konstruksi lebih sederhana

B. Dasar Pemilihan Koil Pendingin

Luas area transfer panas reaktor lebih besar dibandingkan dengan luas selimut reaktor.

C. Dasar Pemilihan Pengaduk

Menentukan jenis pengaduk dilihat berdasarkan nilai viskositas cairan yang diaduk dan volume cairan yang diaduk. Sehingga dipilih pengaduk tipe *Flat Blade Turbines Impellers* dengan pertimbangan sebagai berikut:

a. Efektif untuk menjangkau viskositas yang cukup luas

b. Cocok untuk cairan dengan viskositas mencapai 50000 cP

D. Neraca Massa

Umpan masuk

Komponen	BM	Kg/jam	Kmol/jam
NaOH	40,000	1333,953	33,349
Na_2CO_3 (impuritis)	105,990	0,544	0,005
NaCl (impuritis)	58,440	0,408	0,007
Fe (impuritis)	55,850	0,014	0,000
Na_2SO_4 (impuritis)	142,060	0,544	0,004
HNO_3	63,060	2102,223	33,349
H_2O (impuritis)	18,010	3875,648	215,194
TOTAL		7312,422	281,908

Umpan keluar

Komponen	BM	Kg/jam	Kmol/jam
NaOH	40,000	200,093	5,002
Na_2CO_3 (impuritis)	105,990	0,544	0,005
NaCl (impuritis)	58,440	0,408	0,007
Fe (impuritis)	55,850	0,014	0,000
Na_2SO_4 (impuritis)	142,060	0,544	0,004
HNO_3	63,060	35,196	5,002
$NaNO_3$	85,000	2409,453	28,347
H_2O (impuritis)	18,010	4386,169	243,541
TOTAL		7312,422	281,908

E. Menentukan densitas dan viskositas cairan

Suhu = 60°C

= 333 K

Data denstitas *liquid* diperoleh dari Table 8-1 dan 8-2, Yaws dan Aplikasi Aspen

$$\rho = A\,.\,B^{-(1-T/T_c)^n}$$

Tabel A.2. Perhitungan Densitas *Liquid*

Komponen	A	B	N	Tc	ρ (kg/m3)
NaOH	0,200	0,908	0,254	2820	1896,244
Na_2CO_3					2533,000
NaCl	0,221	0,106	0,375	3400	1918,621
Fe	0,571	0,070	0,286	9341	7935,400
Na2SO4	0,261	0,100	0,266	3700	2469,302
HNO3	0,435	0,231	0,192	520	1449,222
NaNO3					2257,000
H_2O	0,347	0,274	0,286	647,130	994,960

$$Fv = \frac{massa(Kg/Jam)}{\rho(Kg/m^3)}$$

Komponen	Massa (kg/jam)	Fraksi massa (xi)	ρ (kg/m3)	ρ .xi	Fv
NaOH	1333,953	0,182	1896,244	345,918	0,703
Na_2CO_3	0,544	0,000	2533,000	0,198	0,000
NaCl	0,408	0,000	1918,621	0,107	0,000
Fe	0,014	0,000	7935,400	0,015	0,000
Na2SO4	0,544	0,000	2469,302	0,184	0,000
HNO3	2101,310	0,287	1449,222	416,451	1,450
H_2O	3875,648	0,530	994,960	527,338	3,895
Total	7312,422	281,908		1290,201	6,049

F. Kinetika Reaksi

$$Fv = \frac{\text{massa umpan}}{\rho \text{ campuran}}$$

= 5,667 m^3/jam

= 5667,660 liter/jam

Cao = na/Fv

= 0,006 kmol/liter

Cbo = nb/Fv

= 0,006 kmol/liter

Reaksi :

$$NaOH + HNO_3 \longrightarrow NaNO_3 + H_2O$$

m :	Cao	Cbo		
r :	Cao.x	Cao.x	Cao.x	Cao.x
s :	Cao-Cao.x	Cbo-Cao.x	Cao.x	Cao.x

Reaksi merupakan reaksi orde dua, dimana kecepatan reaksi dinyatakan dengan:

-ra = k.Ca.Cb

x = 0,98

t = 1 jam

Ca = Cao - Cao.x

= 0,00012 kmol/L

Cb = Cbo - Cao.x

= 0,00012 kmol/L

$$k = \frac{\mathrm{CA0}\ x}{t\ \mathrm{CA0}\ (1-x)(\mathrm{CB0} - \mathrm{CA0}\ x)}$$

= 416379,456 L/kmol.Jam

G. Menentukan Volume Reaktor

Rate of Input - Rate of Output - Rate of Reaction = Accumulation

Fv.Cao - Fv. Ca - (-ra).V = 0

Fv.Cao - Fv. Cao (1-x) - (k.Ca.Cb).V = 0

Fv.Cao - Fv. Cao (1-x) = (k.Ca.Cb). V

$$V = \frac{Fv\ (Cao - Cao\ (1-x))}{k.Ca.Cb}$$

$$V = \frac{Fv.\ Cao.\ X}{k.Ca.Cb}$$

V = 5668 L

= 5,668 m^3

H. Optimasi Reaktor Alir Tangki Berpengaduk

$$\mathbf{V_n} = \frac{\mathbf{FA_o}\,.\,(\mathbf{X_{out}} - \mathbf{X_{in}})}{(-\boldsymbol{ra})_{\boldsymbol{out}}}$$ Fogler hal. 47

$$\mathbf{V_n} = \frac{\mathbf{FA_o}\,.\,(\mathbf{X_{out}} - \mathbf{X_{in}})}{\boldsymbol{k.Ca.Cb}}$$

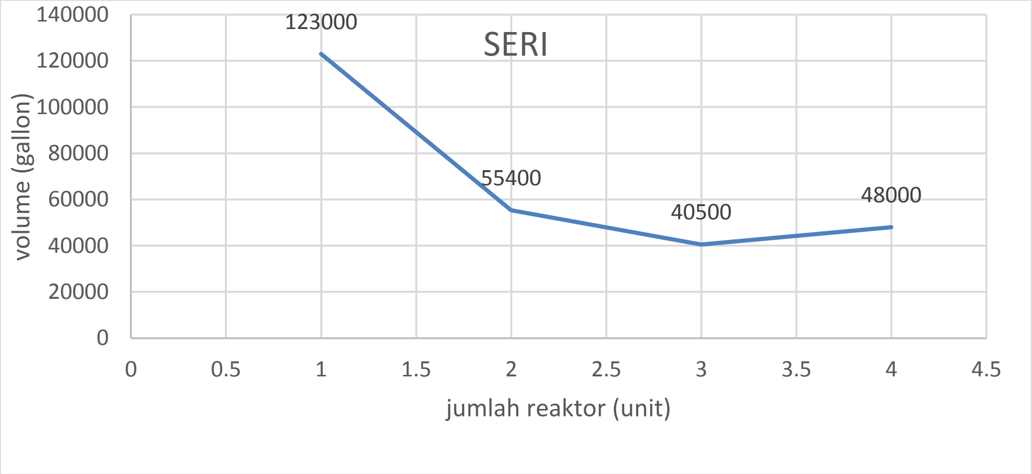
$$\mathbf{V_n} = \frac{\mathbf{FA_o}\,.\,(\mathbf{X_{out}} - \mathbf{X_{in}})}{\boldsymbol{k.Cao}\,(\mathbf{1} - \boldsymbol{X_{out}}).(\boldsymbol{Cbo} - \boldsymbol{Cao.X_{out}})}$$

Dengan menggunakan ketiga persamaan diatas, dapat dicari optimasi reactor dengan metode trial dan error, sehingga didapat hasilnya sebagai berikut,

Reaktor ke-	Xa, N-1	Xa, N	V (L)	Error V
1	0%	98%	5668	0
1	0%	92%	341	0
2	92%	98%	341	0
1	0%	85%	87	0
2	85%	95%	87	0
3	95%	98%	87	0
1	0%	77%	34	0
2	77%	90%	34	0
3	96%	97%	34	0
4	97%	98%	34	0

n	Konversi	Volume (L)	Volume (gallon)	V over design (gallon)	Harga ($) Unit	Harga ($) Total
1	98%	5668	1497	1797	123000	123000
1	92%	341	90	108	27700	55400
2	98%	341	90	108	27700	
1	85%	87	23	28	13500	40500
2	95%	87	23	28	13500	
3	98%	87	23	28	13500	
1	77%	34	9	11	12000	48000
2	90%	34	9	11	12000	
3	97%	34	9	11	12000	
4	98%	34	9	11	12000	

Jumlah Reaktor	Harga
1	123000
2	55400
3	40500
4	48000



Maka, jumlah reaktor yang optimum untuk mendapatkan harga perancangan reaktor yang minimum adalah sebanyak 3 buah.

I. Perancangan Reaktor

1. Dimensi Reaktor

Asumsi :

- Volume cairan selama reaksi tetap
- Kondisi isothermal

Volume shell = 0,087 m3

Over design = 20%

Volume reactor = 1,2 x 0,087 m3

= 0,105 m3

Perbandingan diameter dan tinggi reactor yang optimum adalah D=H, karena jika H/D terlalu besar atau terlalu kecil maka :

- Pengadukan tidak sempurna
- Ada gradien konsentrasi di dalam reaktor
- Distribusi panas tidak merata

$$V_{Shell} = \frac{\pi}{4} D^2 H$$

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

$$D = \sqrt[3]{\frac{V_{Shell}}{\pi}}$$

$$D = \sqrt[3]{\frac{0,105}{3,14}}$$

$$D = H = 0,511\ m = 20,126\ inchi = 1,677\ ft$$

Bentuk reactor adalah vessel dengan silinder tegak dengan head berbentuk torispherical dished head,

$$V_{Head} = 2(V_{dish} + V_{sf})$$

$$V_{Head} = 0,000049 D^3 + \frac{\pi}{4} D^2 \frac{sf}{144}$$

$$V_{Head} = 0,000049(20,126)^3 + \frac{3,14}{4}(20,126)^2 \frac{2}{144}$$

$$V_{Head} = 0,804\ ft^3 = 0,023\ m^3$$

$$V_{Reaktor} = V_{Shell} + V_{Head}$$

$$V_{Reaktor} = (0{,}105 + 0{,}023)m^3$$

$$V_{Reaktor} = 0{,}128\ m^3$$

$$V_{Bottom} = 0{,}5V_{Head}$$

$$V_{Bottom} = 0{,}5V_{Head}$$

$$V_{Bottom} = 0{,}5\ x\ 0{,}023$$

$$V_{Bottom} = 0{,}011m^3$$

$$V_{Cairan} = V_{Shell} - V_{Bottom}$$

$$V_{Cairan} = (0{,}105 - 0{,}011)m^3$$

$$V_{Cairan} = 0{,}093\ m^3$$

$$H_{Cairan} = \frac{4V_{Cairan}}{\pi D^2}$$

$$H_{Cairan} = \frac{4\ x\ 0{,}093}{3{,}14\ x\ 0{,}511^2}$$

$$H_{Cairan} = 0{,}456\ m$$

$$V_{Cairan\ dalam\ shell} = V_{Cairan} - V_{Head} - V_{Sf}$$

$$V_{Cairan\ dalam\ shell} = (0,o87 - 0{,}023 - 0{,}00007)m^3$$

$$V_{Cairan\ dalam\ shell} = 0{,}065\ m^3$$

2. Tebal Shell Reaktor

- Tekanan Total

$$P_{Total} = P_{Hidrostatis} + P_{Operasi}$$

$$P_{Total} = \frac{\rho gh}{gc} + P_{Operasi}$$

$$P_{Total} = \frac{(1290{,}201\ x0{,}456)kg}{m^2} + 14{,}696\ psi$$

$$P_{Total} = 15{,}532\ psi$$

- Tekanan Desain

Over desain = 20%

$P_{Desain} = 1,2\ x\ 15,532\ \ psi$

$P_{Desain} = 1,2\ x\ 15,532\ \ psi$

$P_{Desain} = 18,639\ psi$

- Tebal Shell

Diketahui:

P desain	= 18,639	psi
r	= 0,256	inchi
E	= 0,85	
C	= 0,125	
f	= 18750 psi	

$$ts = \frac{Pr}{(fE - 0,6P)} + C$$

$$ts = \frac{18,639\ x\ 0,256}{(18750\ x\ 0,85 - 0,6\ x\ 18,639)} + 0,125$$

$ts = 0,125\ inchi$

Diambil Ts standart sebesar 0,188 atau 3/16

3. Tebal Head Reaktor

- Tekanan

$P = P_{Desain} - P_{Operasi}$

$P = (18,639 - 14,696)psi$

$P = 3,943\ psi$

- Menentukan OD

$OD = ID_{Shell} - 2ts$

$OD = \left[20,126 - 2x\left({}^{3}/_{16}\right)\right]inchi$

$OD = 20,501\ inchi = 0,521\ m$

Dipilih ukuran OD standart, didapatkan

OD = 22 inchi

Ts = 3/16 inchi

Icr = 1,375 inchi

r = 21 inchi

E = 0,85

C = 0,125

f = 18750

$$w = \frac{1}{4}\left(3 + \sqrt{\frac{r}{icr}}\right)$$

$$w = \frac{1}{4}\left(3 + \sqrt{\frac{21}{1,375}}\right)$$

$$w = 1,727\ inchi$$

- Tebal Head

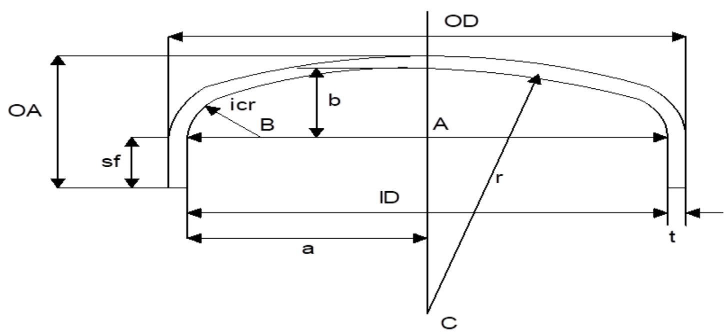
$$th = \frac{Prw}{(2fE - 0,2P)} + C$$

$$th = \frac{3,943\ x\ 0,256\ x1,727}{(2\ x\ 18750\ x\ 0,85 - 0,2\ x\ 3,943)} + 0,125$$

$$th = 0,125\ inchi$$

Diambil Ts standart sebesar 0,188 atau 3/16

4. Tinggi Head Reaktor



Dengan th sebesar 3/16 inchi, maka nilai sf berkisar 1,5-2 inchi. Dipilih nilai sf 2 inchi

$ID = OD - 2ts$

$ID = \left[22 - 2x\left({}^{3}/_{16}\right)\right] inchi$

$ID = 21{,}625\ inchi$

$a = \frac{ID}{2}$

$a = \frac{21{,}625}{2}$

$a = 10{,}813\ inchi$

$AB = a - icr$

$AB = (10{,}813\ - 1{,}375\ ) inchi$

$AB = 9{,}438\ inchi$

$BC = r - icr$

$BC = (21 - 1{,}375\ )\ inchi$

$BC = 19{,}625\ inchi$

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

$AC = \sqrt{19{,}625\ ^2 - 9{,}438\ ^2}$

$AC = 17{,}207\ inchi$

$b = r - AC$

$b = (21 - 17{,}207\ ) inchi$

$b = 3{,}793\ inchi$

$H_{Head} = th + b + sf$

$H_{Head} = \left[\left({}^{3}/_{16}\right) + 3{,}793 + 2\right]\ inchi$

$H_{Head} = \left[\left({}^{3}/_{16}\right) + 3{,}793 + 2\right]\ inchi$

$H_{Head} = 5{,}981\ inchi = 0{,}152\ m$

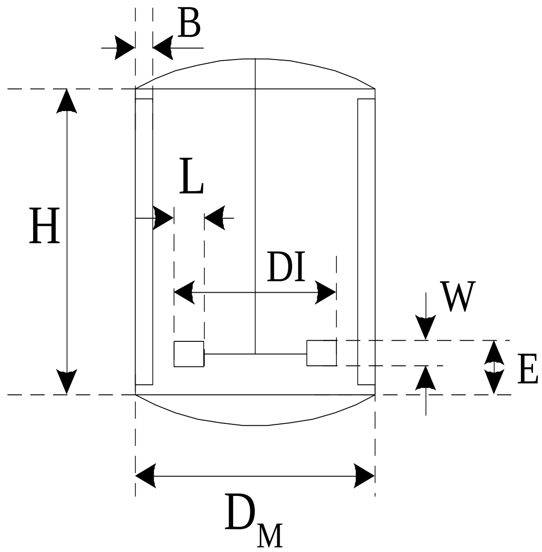
$H_{Reaktor} = 2H_{Head} + H_{Shell}$

$H_{Reaktor} = \left((2\ x0{,}152\ ) + 0{,}511\right) m$

$H_{Reaktor} = 0{,}815\ m$

5. Menentukan Spesifikasi Pengaduk

Untuk viskositas 0,976 cP, maka jenis pengaduk yang dipilih adalah *Flat Blade Turbines Impeller*



Menurut Holland, F.A dan F.S., jenis tipe pengaduk tersebut mempunyai 6 blade dan reactor dilengkapi 4 baffle.

$$D_M = D_{Shell}$$

$$D_M = 0{,}511\ m$$

$$D_I = \frac{D_M}{3}$$

$$D_I = \frac{0{,}511}{3}$$

$$D_I = 0{,}170\ m$$

$$E = \frac{D_M}{3}$$

$$E = \frac{0{,}511}{3}$$

$$E = 0{,}170\ m$$

$$B = \frac{D_M}{12}$$

$$B = \frac{0{,}511}{12}$$

$$B = 0{,}043\ m$$

$$L = \frac{D_I}{4}$$

$$L = \frac{0,170}{4}$$

$$L = 0,043\ m$$

$$W = \frac{D_M}{5}$$

$$W = \frac{0,511}{5}$$

$$W = 0,102\ m$$

$$H = D_M$$

$$H = 0,511\ m$$

6. Menghitung Jumlah Impeller

$$sg = \frac{\rho_{Cairan}}{\rho_{Air}}$$

$$sg = \frac{1290,201}{994,960}$$

$$sg = 1,297$$

$$WELH = H_{Cairan}\ x\ sg$$

$$WELH = 0,456\ x\ 1,297$$

$$WELH = 0,591\ m = 1,939\ ft$$

$$\Sigma_{Impeller} = \frac{WELH}{D}$$

$$\Sigma_{Impeller} = \frac{0,591}{0,511}$$

$$\Sigma_{Impeller} = 1,156 = 2$$

7. Menentukan Putaran Pengaduk

$$\frac{WELH}{2D_I} = \left(\frac{\pi D_I N}{600}\right)$$

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

$$N = \frac{600}{3{,}14\ x\ 0{,}559\ ft}\sqrt{\frac{1{,}939\ \ ft}{2\ x\ 0{,}559ft}}$$

$$N = 314{,}069\ rpm = 5{,}324\ rps$$

Dipilih jenis motor tipe fixed speed belt, dengan kecepatan motor standard 320 rpm atau 5,333 rps.

8. Menentukan Daya Motor

$$R_E = \frac{\rho_L N D_I^2}{\mu_L}$$

$$R_E = \frac{80{,}545\ x\ 5{,}333\ x\ 0{,}559^2}{8{,}69E^{-02}}$$

$$R_E = 1544{,}584$$

Berdasakan figure 10.59, Towler dan Sinnot, untuk Re bernilai 431477,249 maka, nilai Np sebesar 5.

$$P = \frac{N^3 D_I^5 \rho N_p}{550gc}$$

$$P = \frac{5{,}333^3\ x\ 0{,}559^5\ x\ 80{,}545\ x\ 0{,}380}{550\ x\ 32{,}15}$$

$$P = 0{,}014\ HP$$

Berdasarkan figure 14.38 Peters, diambil efisiensi motor sebesar 82%

$$Daya\ Motor = \frac{P}{\eta}$$

$$Daya\ Motor = \frac{0{,}014\ \ HP}{82\%}$$

$$Daya\ Motor = 0{,}017\ HP$$

Dipilih daya motor standart sebesar 0,05 HP

Reaktor 1

J. Neraca Panas

- Arus Masuk

Komponen	Kmol	∫Cp dT	Q(Kj)
NaOH	33,349	3067,004	102281,004
Na_2CO_3	0,005	5390,000	27,688
NaCl	0,007	3306,539	23,105
Fe	0	2219,105	0,541
Na_2SO_4	0,004	8166,700	31,300
HNO_3	33,348	7057,844	235370,841
H_2O	215,194	3194,568	687452,712
Total			1025187,192

- Arus Keluar

Komponen	Kmol	∫Cp dT	Q (KJ)
NaOH	5,002	3067,004	15342,151
Na_2CO_3	0,005	5390,000	27,688
NaCl	0,007	3306,539	23,105
Fe	0	2219,105	0,541
Na_2SO_4	0,004	8166,700	31,300
HNO_3	5,002	7057,844	35305,626
$NaNO_3$	28.347	4980,500	141179,771
H_2O	243,541	3194,568	778007,563
Total			969917,745

- Panas Reaksi

Komponen	ṅ reaksi	n reaksi	ΔH°f	Q standar
	kmol/jam	Mol/jam	kJ/mol	kJ/jam
NaOH	28,347	28346,506	-425,600	-12064272,74
HNO_3	28,347	28346,506	-135,100	-3829612,893
$NaNO_3$	28,347	28346,506	-467.395	-13249014,94
H_2O	28,347	28346,506	-241.800	-6854185,03
Total				-35997085,60

Q standar = ṅ . $\Delta H^o f_{produk}$ - ṅ . $\Delta H^o f_{reaktan}$

Q standar = (-20103199,97 kJ/jam) – (-15893885,63kJ/jam)

Q standar = -4209314,334 kJ/jam

Q reaksi = Q standar + Q output – Q input

Q reaksi = (-4209314,334 kJ/jam) + (969917,745 kJ/jam) – (1025187,192 kJ/jam)

Q reaksi = -4264583,781 kJ/jam→ Eksotermis

Keterangan	Q_{input} (kJ/jam)	Q_{output} (kJ/jam)
Input	1025187,1918	-
Output	-	969917,7448
Reaksi	4264583,7812	-
Pendingin	-	4319853,2282
Total	5289770,9730	5289770,9730

- Kebutuhan Pendingin

Diketahui,

Q = 4319853,228 kJ

Cp air = 4,148 Kj/Kg^{O}C

T in =30 ^{o}C

T out = 40 ^{o}C

$$m_{pendingin} = \frac{Q}{C_P(T_{out} - T_{in})}$$

$$m_{pendingin} = \frac{4319853{,}2282\ kJ}{4{,}148\ Kj/Kg°C(40 - 30)°C}$$

$$m_{pendingin} = 104143{,}038\ kg$$

K. Penentuan dan Perancangan Pendingin

$\rho_{air\ pada\ 313\ K}$ = 1018,4091 kg/m^3

1. Log Mean Temperature Defferensial

T_{in} pendingin = 30^{o}C = 303 K

T_{out} pendingin = 40^{o}C = 313 K

T_{in} larutan = 60^{o}C = 333 K

T_{out} larutan = 60^{o}C = 333 K

Inisial	Fluida Panas (^{o}F)		Fluida Dingin (^{o}F)	ΔT (^{o}F)
ΔT2	140	Lower Temp	86	54
ΔT1	140	Higher Temp	104	36

$$\Delta T_{LMTD} = \frac{\Delta T_2 - \Delta T_1}{Ln\frac{\Delta T_2}{\Delta T_1}}$$

$$\Delta T_{LMTD} = \frac{54 - 36}{Ln\frac{54}{36}}$$

$\Delta T_{LMTD} = 44{,}394$ °F

2. Menghitung luas transfer panas

Diketahui,

$Q_{Pendingin}$ = 4319853,228 Kj/Jam = 4095220,86 Btu/Jam

Untuk cold fluid dimana water dan hot fluid dengan viskositas light organic, nilai Ud berkisar antara 75-150 Btu/ft^{2o}FJam. Diambil nilai Ud 100 btu/ft^{2o}FJam.

Maka nilai luas transfer panas dapat dihitung dengan persamaan berikut,

$$A = \frac{Q}{Udx\Delta T_{LMTD}}$$

$$A = \frac{4095220{,}86}{100\ x\ 44{,}394}$$

$$A = 922{,}483\ ft^2 = 85{,}699\ m^2$$

3. Menghitung luas selubung reactor

$$L = \pi Dl$$

$$L = 3{,}14\ x\ 0{,}511\ x\ 0{,}511$$

$$L = 0{,}821\ m^2$$

Luas selimut < A (luas transfer panas) terhitung, sehingga luas selimut tidak mencukupi sebagai luas transfer panas, maka digunakan *coil* pendingin.

4. Menentukan Kecepatan Volumetrik Air

- Data fisis air pada suhu 30°C

Cp = 4,1799 kJ/kg.K = 17,9819 kcal/kmol.K

ρ = 994,0320 kg/m3

$$Q_v = \frac{W_t}{\rho_{air}}$$

$$Q_v = \frac{104143{,}04}{994{,}032}$$

$$Q_v = 104{,}768\ {}^{m^3}/_{Jam}$$

5. Menentukan Diameter Minimum Koil

Untuk aliran dalam koil/tube, batasan kecepatan antara 1,5-2,5 m/s

Dipilih,

Kecepatan pendingin = 2 m/s

Debit air pendingin = 104,768 m^3/jam

v = 2 m/s = 7200 m/jam

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

$A = \frac{104,768}{7200}$

$A = 0,015\ m^2 = 0,157\ ft^2 = 22,554\ inchi^2$

$ID = \sqrt{\frac{4A}{\pi}}$

$ID = \sqrt{\frac{4\ x\ 0,015}{3,14}}$

$ID = 0,136\ m = 5,36\ inchi$

Dipilih diameter standart,

NPS = 6 inchi

Schedule Number = 80

OD = 6,625 inchi = 0,5521 ft = 0,168 m

ID = 5,761 inchi = 0,480 ft = 0,146 m

Luas Penampang (A') = 26,100 $inchi^2$ = 0,181 ft^2

Luas Perpan/panjang (a'') = 1,734 ft^2/ft

6. Menentukan hi

$\rho_{air\ pendingin}$ = 1018,409 kg/m^3 = 63,5487 lb/ft^3

$\mu_{air\ pendingin}$ = 0,7356 cP = 1,779 lb/ft.jam

$k_{air\ pendingin}$ = 0,619 W/m.K = 0,358 Btu/ftjam^{o}F

$Cp_{air\ pendingin}$ = 25604,916 kJ/kmol = 1421,284 kJ/kg = 611,152 Btu/lb

- Menentukan kecepatan aliran massa/luas penampang

$G_t = \frac{W}{A}$

$G_t = \frac{229596,08}{0,181}$

$G_t = 1266737,009\ lb/ft^2jam$

$$v = \frac{G_t}{\rho}$$

$$v = \frac{1266737{,}009}{63{,}5487}$$

$$v = 19933{,}318\,\frac{ft}{jam} = 1{,}688\,\frac{m}{s} = 5{,}54\ ft/s$$

Jadi kecepatan pendingin yang digunakan masih dalam batasan.

- Menentukan Bilangan Reynold (Re)

$$Re = \frac{0{,}480\ x\ 1266737{,}009}{1{,}7794}$$

$$Re = 341769{,}538$$

Re > 4000, maka aliran turbulen.

Dengan nilai Re 341769,538 maka didapatkan nilai jH sebesar 100

- Menentukan nilai hi

$$hi = jH\ x\ \frac{k}{De}\,x\left(\frac{c\mu}{k}\right)^{\frac{1}{3}}x\left(\frac{\mu}{\mu_w}\right)^{0{,}14}$$

$$hi = 100\ x\ \frac{0{,}358}{0{,}480}\,x\left(\frac{611{,}152\ x\ 1{,}779}{0{,}358}\right)^{\frac{1}{3}}x(1)^{0{,}14}$$

$$hi = 1080{,}024\ btu/ft^2 jam°F$$

- Menentukan nilai hio

$$h_{io} = hi\,\frac{ID}{OD}$$

$$h_{io} = 1080{,}024x\,\frac{0{,}480}{0{,}552}$$

$$h_{io} = 939{,}172\ btu/ft^2 jam°F$$

Untuk koil, harga hio harus dikoreksi dengan factor koreksi,

$$hio_{koil} = hio_{pipa}\left(1 + 3{,}5\,\frac{D_{Koil}}{D_{SpiralKoil}}\right)$$

Diambil $D_{spiral\ koil}$ = 70% x Diameter tangki

$$D_{spiral} = 70\%\ x\ 20{,}126$$

$$D_{spiral} = 14{,}088\ inchi = 1{,}174\ ft$$

$$hio_{koil} = 939{,}172\ x\left(1 + 3{,}5x\,\frac{0{,}480}{1{,}174}\right)$$

$$hio_{koil} = 2283{,}873\ btu/ft^2 jam°F$$

- Menentukan ho

Diketahui,

Lp = Di = 0,5591 ft

N = 320 rpm = 5,333 rps = 19200 rpj

P = 1290,2012 kg/m^3 = 80,508 lb/ft^3

μ = 129,358 cp = 313,046 lb/ft.jam

cp = 37382,260 kJ/kg = 8928,600 Btu/lb

k = 0,620 Btu/ft.j.°F

OD = 6,625 inchi = 0,552 ft

D = 21,625 inchi = 1,801 ft

μ/μw = 1

$$h_o = 0{,}87\left(\frac{k}{D}\right)\left(\frac{{L_p}^2 N\rho}{\mu}\right)^{\frac{2}{3}}\left(\frac{cp\mu}{k}\right)^{\frac{1}{3}}\left(\frac{\mu}{\mu_w}\right)^{0,4}$$

$$h_o = 76279{,}04\ Btu/jamft^2°F$$

- Menentukan Uc

$$Uc = \frac{ho\ x\ hio}{ho + hio}$$

$$Uc = \frac{76279{,}04\ x\ 2283{,}873}{76279{,}04 +\ 2283{,}873}$$

$$Uc = 2217{,}479\ Btu/jamft^2°F$$

- Menentukan Ud

Untuk kecepatan air = 2 m/s, maka Rd sebesar 0,001, sehingga diperoleh,

$$h_D = \frac{1}{Rd}$$

$$h_D = \frac{1}{0{,}001}$$

$$h_D = 1000\ Btu/jamft^2 °F$$

$$U_D = \frac{h_D\ x\ Uc}{h_D +\ Uc}$$

$$U_D = \frac{1000\ x\ 2217{,}479}{1000 + 2217{,}479}$$

$$U_D = 689{,}197\ Btu/Jamft^2 °F$$

- Menentukan Luas Bidang Transfer Panas

$$A = \frac{Q_{Total}}{U_D\ x\ \Delta LMTD}$$

$$A = \frac{4095220{,}86}{689{,}197\ x\ 44{,}394}$$

$$A = 133{,}849 ft^2$$

- Menentukan Panjang Koil

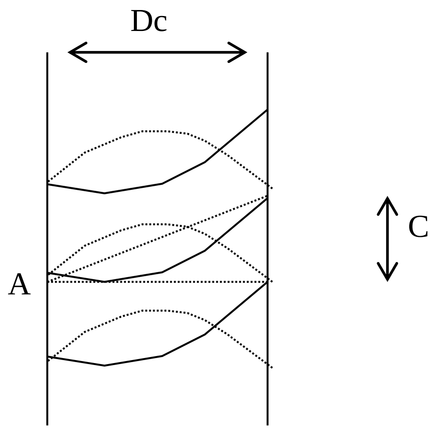
$$L_{Pipa\ Koil} = \frac{A}{a"}$$

$$L_{Pipa\ Koil} = \frac{133{,}849}{1{,}734}$$

$$L_{Pipa\ Koil} = 77{,}1908\ ft = 23{,}528\ m$$

- Menentukan Jumlah Lengkungan Koil

$D_C = 70\% \ x \ D_{Tangki \ Reaktor}$



$D_C = 70\% \ x \ 21{,}625$

$D_C = 15{,}137 \ inchi = 1{,}26 \ ft$

AB = ID

BC = X

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

$AC = \sqrt{(ID)^2 + (X)^2}$

$Busur \ AB = \frac{1}{2}\pi D_C$

$Busur \ AC = \frac{1}{2}\pi AC$

Diambil,

$X = 0{,}5 \ x \ OD$

$X = 0{,}5 \ x \ 6{,}625$

$X = 3{,}312 inchi = 0{,}276 \ ft$

Panjang satu putaran,

$K_{Lilitan} = \frac{1}{2} Putaran \ Miring + \frac{1}{2} Putaran \ Datar$

$K_{Lilitan} = \frac{1}{2}\pi D_C + \frac{1}{2}\pi AC$

$K_{Lilitan} = \frac{1}{2}\pi D_C + \frac{1}{2}\pi \left[(D_C^2 \ x \ X^2)^{1/2}\right]$

$K_{Lilitan} = 4{,}008 \ ft = 48{,}094 \ inchi = 1{,}222 \ m$

- Menentukan Banyakanya Lilitan

$N_{Lilitan} = \frac{L_{Pipa \ Koil}}{K_{Lilitan}}$

$N_{Lilitan} = \frac{77{,}191}{4{,}008}$

$N_{Lilitan} = 19{,}260 = 20 \ Lilitan$

- Menentukan Tinggi Tumpukan dan Tinggi Cairan Setelah Ada Koil

$Tinggi\ Tumpukan_{Koil} = [(N_{Lilitan} - 1)\ x\ X] + (N_{Lilitan}\ x\ OD)$

$Tinggi\ Tumpukan_{Koil} = [(20 - 1)\ x\ 0{,}276] + (20\ x\ 0{,}552)$

$Tinggi\ Tumpukan_{Koil} = 16{,}287\ ft = 4{,}964\ m = 195{,}438\ inchi$

Tinggi cairan dalam shell akan naik karena adanya volume dari koil. Asumsi : koil ada dalam shell saja.

Diketahui,

$V_{Cairan\ Dalam\ Shell} = 0{,}065\ m^3$

$V_{Koil} = \pi D^2 l$

$V_{Koil} = 3{,}14\ x\ (0{,}168)^2\ x\ 23{,}528$

$V_{Koil} = 2{,}092\ m^3$

$A_{Shell} = \frac{1}{4}\pi D^2$

$A_{Shell} = \frac{1}{4}\ x\ 3{,}14\ x\ 0{,}511^2$

$A_{Shell} = 0{,}205\ m^2$

Tinggi Cairan Setelah Ditambah Koil(Z_C)

$Z_C = \frac{V_{Cairan\ dalam\ shell +}\ V_{Koil}}{A_{Shell}}$

$Z_C = \frac{0{,}065 + 2{,}092}{0{,}205}$

$Z_C = 10{,}512\ m = 413{,}859\ inchi$

Tinggi Cairan di dalam reactor setelah ada koil(Z_{C2})

$Z_{C2} = Z_C + b + sf$

$Z_{C2} = 413{,}859 + 3{,}793 + 2$

$Z_{C2} = 419{,}652\ inchi = 10{,}659\ m$

Jarak dari dasar tangki ke bagian bawah koil(hk)

$hk = \frac{\text{Tinggi Cairan Setelah Ada Koil} - \text{Tumpukan Koil}}{2}$

$$hk = \frac{10,659 - 4,964}{2}$$

$$hk = 2,847\ m$$

$$b + sf = (3,793 + 2) inchi$$

$$b + sf = 5,793\ Inchi = 0,147\ m$$

Asumsi dikatakan benar jika,

1. Tinggi Tumpukan Koil < Tinggi Cairan, artinya koil tercelup dalam cairan.
2. Jarak dasar tangki ke bagian bawah koil (hk) > (b+sf), maka asumsi bahwa koil tercelup di shell saja adalah benar.

7. Pressure Drop

$$faktor\ friksi(f) = 0,0035 + \frac{0,264}{Re^{0,42}}$$

$$faktor\ friksi(f) = 0,0035 + \frac{0,264}{(106413,784)^{0,42}}$$

$$faktor\ friksi(f) = 0,00475\ {ft^2}/{in^2}$$

Karena yang mengalir dalam tube adalah steam, s = 1, dan perbedaan suhu tidak terlalu besar, sehingga bisa diasumsikan μ=μw, maka θt=1.

$$\Delta P_T = \frac{f\ x\ v^2\ x\ L}{5,22\ x\ 10^{10}\ x\ ID\ x\ s\ x\ \theta_t}$$

$$\Delta P_T = \frac{0,00475\ x 19933,318^2\ x\ 77,191}{5,22\ x\ 10^{10}\ x\ 0,480\ x\ 1\ x\ 1}$$

$$\Delta P_T = 0,0058\ psi$$

Koil Reaktor 2

L. Neraca Panas

- Arus Masuk

Komponen	Kmol	∫Cp dT	Q(Kj)
NaOH	5,002	3067,004	15342,151
Na_2CO_3	0,005	5390,000	27,688
NaCl	0,007	3306,539	23,105
Fe	0	2219,105	0,541
Na_2SO_4	0,004	8166,700	31,300
HNO_3	5,002	7057,844	35305,626
$NaNO_3$	28,347	4980,500	141179,771
H_2O	243,541	3194,568	778007,563
Total			969917,745

- Arus Keluar

Komponen	Kmol	∫Cp dT	Q (KJ)
NaOH	1,667	3067,004	5114,050
Na_2CO_3	0,005	5390,000	27,688
NaCl	0,007	3306,539	23,105
Fe	0	2219,105	0,541
Na_2SO_4	0,004	8166,700	31,300
HNO_3	1,667	7057,844	11768,542
$NaNO_3$	31,681	4980,500	157789,155
H_2O	246,876	3194,568	788661,075
Total			963415,457

- Panas Reaksi

Komponen	ṅ reaksi	n reaksi	$\Delta H^o f$	Q standar
	kmol/jam	Mol/jam	kJ/mol	kJ/jam
NaOH	3,335	3334,883	-425,600	-1419326,205
HNO_3	3,335	3334,883	-135,100	-450542,6933
$NaNO_3$	3,335	3334,883	-467.395	-1558707,64
H_2O	3,335	3334,883	-241.800	-806374,709
Total				-4234951,247

Q standar = ṅ . $\Delta H^o f_{produk}$ - ṅ . $\Delta H^o f_{reaktan}$

Q standar = (-2365082,349 kJ/jam) – (-1869868,898kJ/jam)

Q standar = -495213,451 kJ/jam

Q reaksi = Q standar + Q output – Q input

Q reaksi = (-495213,451 kJ/jam) + (963415,457 kJ/jam) – (969917,745 kJ/jam)

Q reaksi = -501715,739 kJ/jam→ Eksotermis

Keterangan	Q_{input} (kJ/jam)	Q_{output} (kJ/jam)
Input	969917,7448	-
Output	-	963415,4569
Reaksi	501715,7390	-
Pendingin	-	508218,0269
Total	1471633,4837	1471633,4837

- Kebutuhan Pendingin

Diketahui,

Q = 508218,027 kJ

Cp air = 4,148 Kj/Kg^{O}C

T in =30 ^{o}C

T out = 40 ^{o}C

$$m_{pendingin} = \frac{Q}{C_P(T_{out} - T_{in})}$$

$$m_{pendingin} = \frac{508218{,}027\ kJ}{4{,}148\ Kj/Kg°C(40-30)°C}$$

$$m_{pendingin} = 12252{,}122\ kg$$

M. Penentuan dan Perancangan Pendingin

$\rho_{air\ pada\ 313\ K}$ = 1018,4091 kg/m^3

8. Log Mean Temperature Defferensial

T_{in} pendingin = 30^{o}C = 303 K

T_{out} pendingin = 40^{o}C = 313 K

T_{in} larutan = 60^{o}C = 333 K

T_{out} larutan = 60^{o}C = 333 K

Inisial	Fluida Panas (^{o}F)		Fluida Dingin (^{o}F)	ΔT (^{o}F)
ΔT2	140	Lower Temp	86	54
ΔT1	140	Higher Temp	104	36

$$\Delta T_{LMTD} = \frac{\Delta T_2 - \Delta T_1}{Ln\frac{\Delta T_2}{\Delta T_1}}$$

$$\Delta T_{LMTD} = \frac{54-36}{Ln\frac{54}{36}}$$

$\Delta T_{LMTD} = 44{,}394$ °F

9. Menghitung luas transfer panas

Diketahui,

$Q_{Pendingin}$ = 508218,027 Kj/Jam = 481790,690 Btu/Jam

Untuk cold fluid dimana water dan hot fluid dengan viskositas light organic, nilai Ud berkisar antara 75-150 Btu/ft^{2o}FJam. Diambil nilai Ud 100 btu/ft^{2o}FJam.

Maka nilai luas transfer panas dapat dihitung dengan persamaan berikut,

$$A = \frac{Q}{Udx\Delta T_{LMTD}}$$

$$A = \frac{481790{,}690}{100\ x\ 44{,}394}$$

$$A = 108{,}527\ ft^2 = 10{,}082\ m^2$$

10. Menghitung luas selubung reactor

$$L = \pi Dl$$

$$L = 3{,}14\ x\ 0{,}511\ x\ 0{,}511$$

$$L = 0{,}821\ m^2$$

Luas selimut < A (luas transfer panas) terhitung, sehingga luas selimut tidak mencukupi sebagai luas transfer panas, maka digunakan *coil* pendingin.

11. Menentukan Kecepatan Volumetrik Air

- Data fisis air pada suhu 30°C

Cp = 4,1799 kJ/kg.K = 17,9819 kcal/kmol.K

ρ = 994,0320 kg/m3

$$Q_v = \frac{W_t}{\rho_{air}}$$

$$Q_v = \frac{12252{,}12}{994{,}032}$$

$$Q_v = 12{,}326\ {}^{m^3}/_{Jam}$$

12. Menentukan Diameter Minimum Koil

Untuk aliran dalam koil/tube, batasan kecepatan antara 1,5-2,5 m/s

Dipilih,

Kecepatan pendingin = 2 m/s

Debit air pendingin = 12,326 m^3/jam

v = 2 m/s = 7200 m/jam

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

$$A = \frac{12{,}326}{7200}$$

$$A = 0{,}0017\ m^2 = 0{,}018\ ft^2 = 2{,}653\ inchi^2$$

$$ID = \sqrt{\frac{4A}{\pi}}$$

$$ID = \sqrt{\frac{4\ x\ 0{,}0017}{3{,}14}}$$

$$ID = 0{,}047\ m = 1{,}836\ inchi$$

Dipilih diameter standart,

NPS = 2 inchi

Schedule Number = 80

OD = 2,38 inchi = 0,198 ft = 0,060 m

ID = 1,939 inchi = 0,162 ft = 0,049 m

Luas Penampang (A') = 2,95 inchi^2 = 0,021 ft^2

Luas Perpan/panjang (a'') = 0,622 ft^2/ft

13. Menentukan hi

$\rho_{air\ pendingin}$ = 1018,409 kg/m^3 = 63,5487 lb/ft^3

$\mu_{air\ pendingin}$ = 0,7356 cP = 1,779 lb/ft.jam

$k_{air\ pendingin}$ = 0,619 W/m.K = 0,358 Btu/ftjam^{o}F

$Cp_{air\ pendingin}$ = 25604,916 kJ/kmol = 1421,284 kJ/kg = 611,152 Btu/lb

- Menentukan kecepatan aliran massa/luas penampang

$$G_t = \frac{W}{A}$$

$$G_t = \frac{27011{,}30}{0{,}021}$$

$$G_t = 1318517{,}884\ lb/ft^2jam$$

$$v = \frac{G_t}{\rho}$$

$$v = \frac{1318517{,}884}{63{,}5487}$$

$$v = 20748{,}140 \frac{ft}{jam} = 1{,}757 \frac{m}{s} = 5{,}76\ ft/s$$

Jadi kecepatan pendingin yang digunakan masih dalam batasan.

- Menentukan Bilangan Reynold (Re)

$$Re = \frac{0{,}161\ x\ 1318517{,}884}{1{,}7794}$$

$$Re = 119732{,}721$$

Re > 4000, maka aliran turbulen.

Dengan nilai Re 119732,721 maka didapatkan nilai jH sebesar 180

- Menentukan nilai hi

$$hi = jH\ x\ \frac{k}{De}\ x \left(\frac{c\mu}{k}\right)^{\frac{1}{3}} x \left(\frac{\mu}{\mu_w}\right)^{0{,}14}$$

$$hi = 180\ x\ \frac{0{,}358}{0{,}162}\ x \left(\frac{611{,}152\ x\ 1{,}779}{0{,}358}\right)^{\frac{1}{3}} x(1)^{0{,}14}$$

$$hi = 5775{,}983\ btu/ft^2 jam°\mathrm{F}$$

- Menentukan nilai hio

$$h_{io} = hi \frac{ID}{OD}$$

$$h_{io} = 5775{,}983 x \frac{0{,}162}{0{,}198}$$

$$h_{io} = 4705{,}727\ btu/ft^2 jam°F$$

Untuk koil, harga hio harus dikoreksi dengan factor koreksi,

$$hio_{koil} = hio_{pipa} \left(1 + 3{,}5 \frac{D_{Koil}}{D_{SpiralKoil}}\right)$$

Diambil $D_{\text{spiral koil}}$ = 70% x Diameter tangki

$$D_{spiral} = 70\%\ x\ 20{,}126$$

$$D_{spiral} = 14{,}088\ inchi = 1{,}174\ ft$$

$$hio_{koil} = 4705{,}727\ x \left(1 + 3{,}5 x \frac{0{,}162}{1{,}174}\right)$$

$$hio_{koil} = 6973{,}434\ btu/ft^2 jam°F$$

- Menentukan ho

Diketahui,

Lp = Di = 0,5591 ft

N = 320 rpm = 5,333 rps = 19200 rpj

P = 1455,336 kg/m^3 = 90,813 lb/ft^3

μ = 33,547 cp = 81,183 lb/ft.jam

cp = 37382,260 kJ/kg = 8928,600 Btu/lb

k = 0,620 Btu/ft.j.°F

OD = 2,38 inchi = 0,198 ft

D = 47,625 inchi = 3,967 ft

μ/μw = 1

$$h_o = 0{,}87\left(\frac{k}{D}\right)\left(\frac{{L_p}^2 N\rho}{\mu}\right)^{\frac{2}{3}}\left(\frac{cp\mu}{k}\right)^{\frac{1}{3}}\left(\frac{\mu}{\mu_w}\right)^{0,4}$$

$$h_o = 96071{,}416\ Btu/jamft^2°F$$

- Menentukan Uc

$$Uc = \frac{ho\ x\ hio}{ho + hio}$$

$$Uc = \frac{96071{,}416\ x\ 6973{,}434}{96071{,}416 +\ 6973{,}434}$$

$$Uc = 6501{,}515\ Btu/jamft^2°F$$

- Menentukan Ud

Untuk kecepatan air = 2 m/s, maka Rd sebesar 0,001, sehingga diperoleh,

$$h_D = \frac{1}{Rd}$$

$$h_D = \frac{1}{0{,}001}$$

$$h_D = 1000\ Btu/jamft^2°\text{F}$$

$$U_D = \frac{h_D\ x\ Uc}{h_D +\ Uc}$$

$$U_D = \frac{1000\ x\ 6501{,}515}{1000 + 6501{,}515}$$

$$U_D = 866{,}694\ Btu/Jamft^2°\text{F}$$

- Menentukan Luas Bidang Transfer Panas

$$A = \frac{Q_{Total}}{U_D\ x\ \Delta LMTD}$$

$$A = \frac{481790{,}670}{866{,}694\ x\ 44{,}394}$$

$$A = 12{,}522\ ft^2$$

- Menentukan Panjang Koil

$$L_{Pipa\ Koil} = \frac{A}{a"}$$

$$L_{Pipa\ Koil} = \frac{12{,}522}{0{,}622}$$

$$L_{Pipa\ Koil} = 20{,}132\ ft = 6{,}136\ m$$

- Menentukan Jumlah Lengkungan Koil

$$D_C = 70\%\ x\ D_{Tangki\ Reaktor}$$

$$D_C = 70\%\ x\ 47{,}625$$

$$D_C = 33{,}338\ inchi = 2{,}778\ ft$$

AB = ID

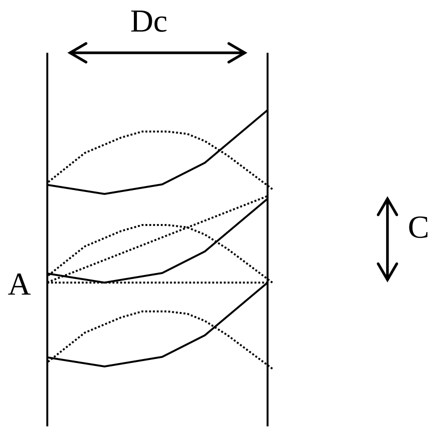
BC = X

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

$$AC = \sqrt{(ID)^2 + (X)^2}$$

$$Busur\ AB = \frac{1}{2}\pi D_C$$

$$Busur\ AC = \frac{1}{2}\pi AC$$



Diambil,

$X = 0{,}5\ x\ OD$

$X = 0{,}5\ x\ 2{,}38$

$X = 1{,}19\ inchi = 0{,}099\ ft$

Panjang satu putaran,

$K_{Lilitan} = \frac{1}{2} Putaran\ Miring + \frac{1}{2} Putaran\ Datar$

$K_{Lilitan} = \frac{1}{2}\pi D_C + \frac{1}{2}\pi AC$

$K_{Lilitan} = \frac{1}{2}\pi D_C + \frac{1}{2}\pi \left[(D_C^2\ x\ X^2)^{1/2}\right]$

$K_{Lilitan} = 8{,}726\ ft = 104{,}713\ inchi = 2{,}660\ m$

- Menentukan Banyakanya Lilitan

$N_{Lilitan} = \frac{L_{Pipa\ Koil}}{K_{Lilitan}}$

$N_{Lilitan} = \frac{20{,}132}{8{,}726}$

$N_{Lilitan} = 2{,}307 = 3\ Lilitan$

- Menentukan Tinggi Tumpukan dan Tinggi Cairan Setelah Ada Koil

$Tinggi\ Tumpukan_{Koil} = [(N_{Lilitan} - 1)\ x\ X] + (N_{Lilitan}\ x\ OD)$

$Tinggi\ Tumpukan_{Koil} = [(3 - 1)\ x\ 0{,}0992] + (3\ x\ 0{,}198)$

$Tinggi\ Tumpukan_{Koil} = 0{,}793\ ft = 0{,}242\ m = 9{,}52\ inchi$

Tinggi cairan dalam shell akan naik karena adanya volume dari koil. Asumsi : koil ada dalam shell saja.

Diketahui,

$V_{Cairan\ Dalam\ Shell} = 0{,}065\ m^3$

$V_{Koil} = \pi D^2 l$

$V_{Koil} = 3{,}14\ x\ (0{,}060)^2\ x\ 6{,}136$

$V_{Koil} = 0{,}070\ m^3$

$$A_{Shell} = \frac{1}{4}\pi D^2$$

$$A_{Shell} = \frac{1}{4}\ x\ 3,14\ x\ 0,511^2$$

$$A_{Shell} = 0,205\ m^2$$

Tinggi Cairan Setelah Ditambah Koil(Z_C)

$$Z_C = \frac{V_{Cairan\ dalam\ shell+}\ V_{Koil}}{A_{Shell}}$$

$$Z_C = \frac{0,065 + 0,070}{0,205}$$

$$Z_C = 0,658\ m = 25,901\ inchi$$

Tinggi Cairan di dalam reactor setelah ada koil(Z_{C2})

$$Z_{C2} = Z_C + b + sf$$

$$Z_{C2} = 413,859 + 3,793 + 2$$

$$Z_{C2} = 419,652\ inchi = 10,659\ m$$

Jarak dari dasar tangki ke bagian bawah koil(hk)

$$hk = \frac{\text{Tinggi Cairan Setelah Ada Koil – Tumpukan Koil}}{2}$$

$$hk = \frac{0,915 - 0,242}{2}$$

$$hk = 0,336\ m$$

$$b + sf = (8,102 + 2)inchi$$

$$b + sf = 10,102\ Inchi = 0,256\ m$$

Asumsi dikatakan benar jika,

3. Tinggi Tumpukan Koil < Tinggi Cairan, artinya koil tercelup dalam cairan.
4. Jarak dasar tangki ke bagian bawah koil (hk) > (b+sf), maka asumsi bahwa koil tercelup di shell saja adalah benar.

14. Pressure Drop

$$faktor\ friksi(f) = 0,0035 + \frac{0,264}{Re^{0,42}}$$

$$faktor\ friksi(f) = 0,0035 + \frac{0,264}{(106413,784)^{0,42}}$$

$$faktor\ friksi(f) = 0{,}0054\ {ft^2}/{in^2}$$

Karena yang mengalir dalam tube adalah steam, s = 1, dan perbedaan suhu tidak terlalu besar, sehingga bisa diasumsikan μ=μw, maka θt=1.

$$\Delta P_T = \frac{f\ x\ v^2\ x\ L}{5{,}22\ x\ 10^{10}\ x\ ID\ x\ s\ x\ \theta_t}$$

$$\Delta P_T = \frac{0{,}0054\ x 20748{,}140^2\ x\ 20{,}132}{5{,}22\ x\ 10^{10}\ x\ 0{,}162 x\ \ 1}$$

$$\Delta P_T = 0{,}0056\ psi$$

- Koil Reaktor 3

Neraca Panas

- Arus Masuk

Komponen	Kmol	∫Cp dT	Q(Kj)
NaOH	5,002	3067,004	15342,151
Na_2CO_3	0,005	5390,000	27,688
NaCl	0,007	3306,539	23,105
Fe	0	2219,105	0,541
Na_2SO_4	0,004	8166,700	31,300
HNO_3	5,002	7057,844	35305,626
$NaNO_3$	28,347	4980,500	141179,771
H_2O	243,541	3194,568	778007,563
Total			969917,745

- Arus Keluar

Komponen	Kmol	∫Cp dT	Q(Kj)
NaOH	1,667	3067,004	5114,050
Na_2CO_3	0,005	5390,000	27,688
NaCl	0,007	3306,539	23,105
Fe	0	2219,105	0,541
Na_2SO_4	0,004	8166,700	31,300
HNO_3	1,667	7057,844	11768,542
$NaNO_3$	31,681	4980,500	157789,155
H_2O	246,876	3194,568	788661,075
Total			963415,457

- Panas Reaksi

Panas Pembentukan Standart

Komponen	ṅ reaksi	n reaksi	$\Delta H^o f$	Q standar
	kmol/jam	Mol/jam	kJ/mol	kJ/jam
NaOH	1,000	1000,645	-425,600	-425797,861
HNO_3	1,000	1000,645	-135,100	-135162,808
$NaNO_3$	1,000	1000,645	-467.395	-467612,413
H_2O	1,000	1000,645	-241.800	-241912,413
Total				-1270485,374

Q standar = ṅ . $\Delta H^o f_{produk}$ - ṅ . $\Delta H^o f_{reaktan}$

Q standar = (-709524,705 kJ/jam) – (-560960,669 kJ/jam)

Q standar = -148564,035 kJ/jam

Q reaksi = Q standar + Q output – Q input

Q reaksi = (-148564,035 kJ/jam) + (963415,457 kJ/jam) – (969917,745 kJ/jam)

Q reaksi = -3678809,924 kJ/jam → Eksotermis

Keterangan	Q_{input} (kJ/jam)	Q_{output} (kJ/jam)
Input	969917,7448	-
Output	-	963415,4569
Reaksi	155066,3232	-
Pendingin	-	161568,6111
Total	1124984,0680	1124984,0680

- Kebutuhan Pendingin

Diketahui,

Q = 161568,611 Kj

Cp air = 4,148 Kj/Kg^{O}C

T in = 30 ^{o}C

T out = 40 ^{o}C

$$m_{pendingin} = \frac{Q}{C_P(T_{out} - T_{in})}$$

$$m_{pendingin} = \frac{161568{,}611 kj}{4{,}148\ Kj/Kg°C(40 - 30)°C}$$

$$m_{pendingin} = 3895{,}097\ kg$$

N. Penentuan dan Perancangan Pendingin

15. Log Mean Temperature Defferensial

T_{in} pendingin = 30^{o}C = 303 K

T_{out} pendingin = 40^{o}C = 313 K

T_{in} larutan = 60^{o}C = 303 K

T_{out} larutan = 60°C = 313 K

Inisial	Fluida Panas (°F)		Fluida Dingin (°F)	ΔT (°F)
ΔT2	140	Lower Temp	86	54
ΔT1	140	Higher Temp	104	36

$$\Delta T_{LMTD} = \frac{\Delta T_2 - \Delta T_1}{Ln\frac{\Delta T_2}{\Delta T_1}}$$

$$\Delta T_{LMTD} = \frac{54 - 36}{Ln\frac{54}{36}}$$

$\Delta T_{LMTD} = 44{,}394$ °F

16. Menghitung luas transfer panas

Diketahui,

$Q_{Pendingin}$ = 161568,611 Kj/Jam = 153167,043 Btu/Jam

Untuk cold fluid dimana water dan hot fluid dengan viskositas light organic, nilai Ud berkisar antara 75-150 btu/ft^{2o}FJam. Diambil nilai Ud 100 btu/ft^{2o}FJam.

Maka nilai luas transfer panas dapat dihitung dengan persamaan berikut,

$$A = \frac{Q}{Udx\Delta T_{LMTD}}$$

$$A = \frac{161568{,}611}{100\ x\ 44{,}394}$$

$A = 34{,}502\ ft^2 = 3{,}205 m^2$

17. Menghitung luas selubung reactor

$L = \pi Dl$

$L = 3{,}14\ x\ 0{,}511\ x\ 0{,}511$

$L = 0{,}821\ m^2$

Luas selimut < A (luas transfer panas) terhitung, sehingga luas selimut tidak mencukupi sebagai luas transfer panas, maka digunakan *coil* pendingin.

18. Menentukan Kecepatan Volumetrik Air

- Data fisis air pada suhu 35°C

Cp = 4,1799 kJ/kg.K = 17,9819 kcal/kmol.K

ρ = 994,0320 kg/m3

$$Q_v = \frac{W_t}{\rho_{air}}$$

$$Q_v = \frac{3895{,}097}{994{,}032}$$

$$Q_v = 3{,}919\ {}^{m^3}/_{Jam}$$

19. Menentukan Diameter Minimum Koil

Untuk aliran dalam koil/tube, batasan kecepatan antara 1,5-2,5 m/s

Dipilih,

Kecepatan pendingin = 2 m/s

Debit air pendingin = 3,919 m^3/jam

v = 2 m/s = 7200 m/jam

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

$$A = \frac{3,919}{7200}$$

$$A = 0,0005\ m^2 = 0,006\ ft^2 = 0,844\ inchi^2$$

$$ID = \sqrt{\frac{4A}{\pi}}$$

$$ID = \sqrt{\frac{4\ x\ 0,0005}{3,14}}$$

$$ID = 0,0263\ m = 1,036\ inchi$$

Dipilih diameter standart,

NPS = 1 inchi

Schedule Number = 40

OD = 1,32 inchi = 0,110 ft = 0,034 m

ID = 1,049 inchi = 0,087 ft = 0,027 m

Luas Penampang (A') = 0,864 $inchi^2$ = 0,006 ft^2

Luas Perpan/panjang (a'') = 0,344 ft^2/ft

20. Menentukan hi

$\rho_{air\ pendingin}$ = 1018,409 kg/m^3 = 63,5487 lb/ft^3

$\mu_{air\ pendingin}$ = 0,7356 cP = 1,779 lb/ft.jam

$k_{air\ pendingin}$ = 0,619 W/m.K = 0,358 Btu/ftjam^{o}F

$Cp_{air\ pendingin}$ = 25604,916 kJ/kmol = 1421,284 kJ/kg = 611,152 Btu/lb

- Menentukan kecepatan aliran massa/luas penampang

$$G_t = \frac{W}{A}$$

$$G_t = \frac{8587,22}{0,006}$$

$$G_t = 1431202,955\ lb/ft^2 jam$$

$$v = \frac{G_t}{\rho}$$

$$v = \frac{1431202,955}{63,548}$$

$$v = 22521,347 \frac{ft}{jam} = 1,907 \frac{m}{s} = 6,26\ ft/s$$

Jadi kecepatan pendingin yang digunakan masih dalam batasan.

- Menentukan Bilangan Reynold (Re)

$$Re = \frac{0,087\ x\ 1431202,955}{1,7794}$$

$$Re = 70311,397$$

Re > 4000, maka aliran turbulen.

Dengan nilai Re 70311,397 maka didapatkan nilai jH sebesar 200

- Menentukan nilai hi

$$hi = jH\ x\ \frac{k}{De} x \left(\frac{c\mu}{k}\right)^{\frac{1}{3}} x \left(\frac{\mu}{\mu_w}\right)^{0,14}$$

$$hi = 200\ x\ \frac{0,358}{0,087} x \left(\frac{11010,114\ x\ 1,779}{0,358}\right)^{\frac{1}{3}} x(1)^{0,14}$$

$$hi = 31098,054\ btu/ft^2 jam°F$$

- Menentukan nilai hio

$$h_{io} = hi \frac{ID}{OD}$$

$$h_{io} = 31098,054 x \frac{0,087}{0,110}$$

$h_{io} = 24713,529\ btu/ft^2 jam°F$

Untuk koil, harga hio harus dikoreksi dengan factor koreksi,

$$hio_{koil} = hio_{pipa}\left(1 + 3,5\frac{D_{Koil}}{D_{SpiralKoil}}\right)$$

Diambil $D_{spiral\ koil}$ = 70% x Diameter tangki

$D_{spiral} = 70\%\ x\ 20,126$

$D_{spiral} = 14,088\ inchi = 1,174\ ft$

$hio_{koil} = 24713,529\ x\left(1 + 3,5x\frac{0,087}{1,174}\right)$

$hio_{koil} = 31156,594\ btu/ft^2 jam°F$

- Menentukan ho

Diketahui,

Lp = Di = 0,559 ft

N = 320 rpm = 5,33 rps = 19200 rpj

P = 1470,878 kg/m^3 = 91,783 lb/ft^3

µ = 24,529 cp = 59,361 lb/ft.jam

cp = 37382,260 kJ/kg = 8928,600 Btu/lb

k = 0,619 Btu/ft.j.°F

OD = 1,32 inchi = 0,110 ft

D = 47,6250 inchi = 3,967 ft

µ/µw = 1

$$h_o = 0,87\left(\frac{k}{D}\right)\left(\frac{{L_p}^2 N\rho}{\mu}\right)^{\frac{2}{3}}\left(\frac{cp\mu}{k}\right)^{\frac{1}{3}}\left(\frac{\mu}{\mu_w}\right)^{0,4}$$

$$h_o = 119633,324\ Btu/jamft^2{}^\circ F$$

- Menentukan Uc

$$Uc = \frac{ho\ x\ hio}{ho + hio}$$

$$Uc = \frac{119633,324\ x\ 31156,594}{119633,324 + 31156,594}$$

$$Uc = 24718,940\ Btu/jamft^2{}^\circ F$$

- Menentukan Ud

Untuk kecepatan air = 2 m/s, maka Rd sebesar 0,001, sehingga diperoleh,

$$h_D = \frac{1}{Rd}$$

$$h_D = \frac{1}{0,001}$$

$$h_D = 1000\ Btu/jamft^2{}^\circ\mathrm{F}$$

$$U_D = \frac{h_D\ x\ Uc}{h_D +\ Uc}$$

$$U_D = \frac{1000\ x\ 24718,940}{1000 +\ 24718,940}$$

$$U_D = 961,118\frac{Btu}{Jamft^2}{}^\circ\mathrm{F}$$

- Menentukan Luas Bidang Transfer Panas

$$A = \frac{Q_{Total}}{U_D\ x\ \Delta LMTD}$$

$$A = \frac{153167,043}{44,394\ x\ 961,118}$$

$$A = 3,590\ ft^2$$

- Menentukan Panjang Koil

$$L_{Pipa\ Koil} = \frac{A}{a"}$$

$$L_{Pipa\ Koil} = \frac{3,590}{0,305}$$

$$L_{Pipa\ Koil} = 10,435\ ft = 3,181\ m$$

- Menentukan Jumlah Lengkungan Koil

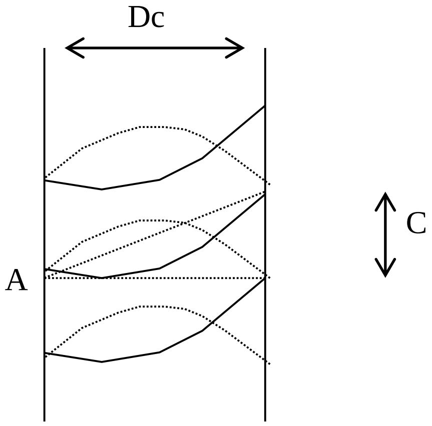
$$D_C = 70\%\ x\ D_{Tangki\ Reaktor}$$

$$D_C = 70\%\ x\ 47,625$$

$$D_C = 33,337\ inchi = 2,778\ ft$$

AB = ID

BC = X



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

$$AC = \sqrt{(ID)^2 + (X)^2}$$

$$Busur\ AB = \frac{1}{2}\pi D_C$$

$$Busur\ AC = \frac{1}{2}\pi AC$$

Diambil,

$X = 0,5\ x\ OD$

$X = 0,5\ x\ 1,32$

$X 0,660\ inchi = 0,055\ ft$

Panjang satu putaran,

$K_{Lilitan} = \frac{1}{2} Putaran\ Miring + \frac{1}{2} Putaran\ Datar$

$$K_{Lilitan} = \frac{1}{2}\pi D_C + \frac{1}{2}\pi AC$$

$K_{Lilitan} = \frac{1}{2}\pi D_C + \frac{1}{2}\pi \left[(D_C^2\ x\ X^2)^{1/2}\right]$

$K_{Lilitan} = \frac{1}{2}\ x\ 3,14\ x\ 2,778 + \frac{1}{2}\ x\ 3,14 \left[(2,778^2\ x 0,055^2)^{1/2}\right]$

$K_{Lilitan} = 8,724\ ft = 104,690\ inchi = 2,659\ m$

- Menentukan Banyakanya Lilitan

$$N_{Lilitan} = \frac{L_{Pipa\ Koil}}{K_{Lilitan}}$$

$$N_{Lilitan} = \frac{10,435}{8,724}$$

$N_{Lilitan} = 1,196 = 2\ Lilitan$

- Menentukan Tinggi Tumpukan dan Tinggi Cairan Setelah Ada Koil

$Tinggi\ Tumpukan_{Koil} = [(N_{Lilitan} - 1)\ x\ X] + (N_{Lilitan}\ x\ OD)$

$Tinggi\ Tumpukan_{Koil} = [(2 - 1)\ x\ 0,055] + (2\ x\ 0,110)$

$Tinggi\ Tumpukan_{Koil} = 0,275\ ft = 0,084\ m = 3,3\ inchi$

Tinggi cairan dalam shell akan naik karena adanya volume dari koil. Asumsi : koil ada dalam shell saja.

Diketahui,

$V_{Cairan\ Dalam\ Shell}$ = 0,065 m^3

$$V_{Koil} = \pi D^2 l$$

$$V_{Koil} = 3{,}14\ x\ (0{,}034)^2\ x\ 3{,}181$$

$$V_{Koil} = 0{,}011\ m^3$$

$$A_{Shell} = \frac{1}{4}\pi D^2$$

$$A_{Shell} = \frac{1}{4}\ x\ 3{,}14\ x\ 0{,}511^2$$

$$A_{Shell} = 0{,}205\ m^2$$

Tinggi Cairan Setelah Ditambah Koil(Z_C)

$$Z_C = \frac{V_{Cairan\ dalam\ shell + V_{Koil}}}{A_{Shell}}$$

$$Z_C = \frac{0{,}065 + 0{,}011}{0{,}205}$$

$$Z_C = 0{,}369 = 14{,}543\ inchi$$

Tinggi Cairan di dalam reactor setelah ada koil(Z_{C2})

$$Z_{C2} = Z_C + b + sf$$

$$Z_{C2} = 14{,}543 + 8{,}102 + 2$$

$$Z_{C2} = 24{,}645\ inchi = 0{,}626\ m$$

Jarak dari dasar tangki ke bagian bawah koil(hk)

$$hk = \frac{\text{Tinggi Cairan Setelah Ada Koil} - \text{Tumpukan Koil}}{2}$$

$$hk = \frac{0{,}626 - 0{,}084}{2}$$

$$hk = 0{,}271\ m$$

$b + sf = (8{,}102 + 2) inchi$

$b + sf = 10{,}102\ Inchi = 0{,}256\ m$

Asumsi dikatakan benar jika,

5. Tinggi Tumpukan Koil < Tinggi Cairan, artinya koil tercelup dalam cairan.
6. Jarak dasar tangki ke bagian bawah koil (hk) > (b+sf), maka asumsi bahwa koil tercelup di shell saja adalah benar.

21. Pressure Drop

$$faktor\ friksi(f) = 0{,}0035 + \frac{0{,}264}{Re^{0{,}42}}$$

$$faktor\ friksi(f) = 0{,}0035 + \frac{0{,}264}{(70311{,}397)^{0{,}42}}$$

$$faktor\ friksi(f) = 0{,}00593\ {ft^2}/{in^2}$$

Karena yang mengalir dalam tube adalah steam, s = 1, dan perbedaan suhu tidak terlalu besar, sehingga bisa diasumsikan μ=μw, maka θt=1.

$$\Delta P_T = \frac{f\ x\ v^2\ x\ L}{5{,}22\ x\ 10^{10}\ x\ ID\ x\ s\ x\ \theta_t}$$

$$\Delta P_T = \frac{0{,}00593\ x 22521{,}135^2\ x\ 10{,}435}{5{,}22\ x\ 10^{10}\ x\ 0{,}087\ x\ 1\ x\ 1}$$

$$\Delta P_T = 0{,}0069\ psi$$