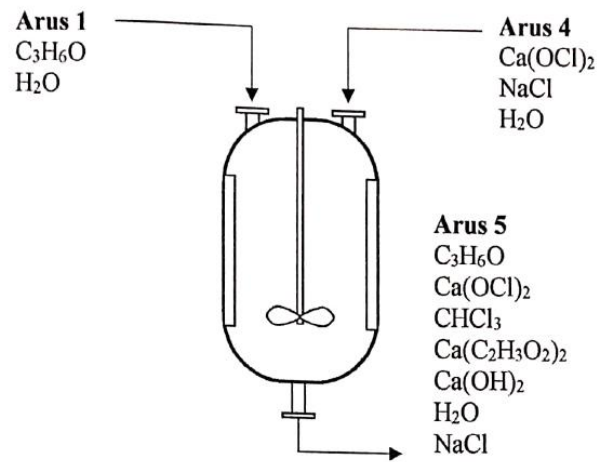


LAMPIRAN A

ALAT BESAR

REAKTOR (R-01)



Tugas : Mereaksikan aseton sebanyak 3134 kg/jam dan kalsium hipoklorit sebanyak 7015 kg/jam menjadi kloroform.

Jenis Alat : Reaktor Alir Tangki Berpengaduk

Kondisi Operasi : Isotermal pada suhu 61 °C dan tekanan 2 atm waktu tinggal 5 menit.

1. Umpan Masuk Reaktor

Komponen	Kmol/jam	W(kg/jam)	$\rho(\text{kg/m}^3)$	$F_v=(W/\rho)$
$\text{C}_3\text{H}_6\text{O}$	53,9730	3134	742,3181	4,2229
$\text{Ca}(\text{OCl})_2$	49,0664	7015	2350	2,9853
H_2O	1189,273	21407	994,0067	21,5360
NaCl	42,8737	2505	2165	1,1573
Total	1335,1860	34062		29,9015

2. Persamaan Laju Reaksi dan Konversi Reaksi

Data yang diperoleh dari literatur Canadian Patent CA 1102355 :

Kondisi Operasi = 61 °C, 2 atm

Waktu Tinggal = 5 menit

Konversi = 97 %

Persamaan laju reaksi diambil dari Canadian Patent CA 1102355 :

Reaksi halogenasi aseton dengan kalsium hipoklorit :



(s)

Secara umum reaksi halogenasi aseton dan kalsium hipoklorit dapat disimbolkan sebagai berikut :



Keterangan :

A = Aseton

D = Kalsium Asetat

B = Kalsium Hipoklorit

E = Kalsium

Hidroksida

C = Kloroform

Orde Reaksi : $-r_B = k C_A C_B$ (Orde 2)

Dianggap : $n_{A0} = 2/3 n_{B0}$

Stoikiometri :

mula-mula	Reaksi	Sisa
2 A n_{A0}	$2/3 X_B n_{B0}$	$n_A = n_{A0} - 2/3 X_B n_{B0}$

2 B n_{B0}	$X_B n_{B0}$	$n_A = n_{B0} (1 - X_B)$
--------------	--------------	--------------------------

$$-r_B = k \cdot C_A \cdot C_B$$

$$-r_B = k \cdot \frac{n_{A0} - \frac{2}{3} X_B \cdot n_{B0}}{V} \cdot \frac{n_{B0}(1 - X_B)}{V}$$

Karena $V = V_0$ dan $n_{A0} = 2/3 n_{B0}$

$$-r_B = k \cdot \frac{\frac{2}{3} n_{B0} - \frac{2}{3} X_B \cdot n_{B0}}{V_0} \cdot \frac{n_{B0}(1 - X_B)}{V_0}$$

$$-r_B = k \cdot \left(\frac{2}{3} C_{B0} - \frac{2}{3} X_B C_{B0} \right) \cdot C_{B0}(1 - X_B)$$

$$-r_B = k \cdot \frac{2}{3} C_{B0}(1 - X_B) \cdot C_{B0}(1 - X_B)$$

$$(-r_B) = \frac{2}{3} k \cdot C_{B0}^2 (1 - X_B)^2 \quad (1)$$

Dengan :

Asumsi yang digunakan

1. Reaksi berlangsung isothermal.
2. Sifat fisis komponen-komponen di dalam reaktor tetap.
3. Reaksi berjalan *steady state*.



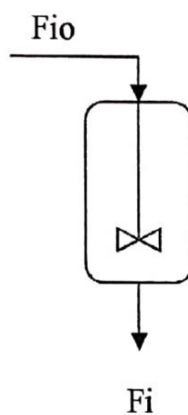
Dengan : A = Aseton D = Kalsium Asetat

 B = Kalsium Hipoklorit E = Kalsium

Hidroksida

 C = Kloroform

Untuk 1 buah RATB :



Neraca massa komponen B di dalam RATB :

Rate of mass input – Rate of mass output – Rate of mass react = Rate of mass acc

$$F_{B0} - F_{B1} - ((-r_B) \cdot V) = 0$$

$$F_V C_{B0} - F_V C_{B1} = -r_B \cdot V$$

$$F_V C_{B0} - F_V C_{B1}(1-X_B) = -r_B \cdot V$$

$$F_V C_{B0} - F_V C_{B0} + F_V C_{B0} X_B = 2/3 k \cdot C_{B0}^2 (1-X_B)^2 V$$

$$F_V C_{B0} X_B = 2/3 k \cdot C_{B0}^2 (1-X_B)^2 V \quad (2)$$

$$k = \frac{3}{2} \cdot \frac{X_B}{C_{B0}(1-X_B)^2} \cdot \frac{F}{V}$$

Dimana $\frac{V}{F} = \theta$

$$k = \frac{3 \cdot X_B}{2 \cdot C_{B0} \cdot \theta (1-X_B)^2}$$

Diketahui

$$X_B = 0,97$$

$$C_{B0} = \frac{n_{B0}}{F_v} = \frac{49,0664}{100,1451} = 0,4900 \frac{kmol}{m^3}$$

$$\theta = 5 \text{ menit} = 300 \text{ detik}$$

sehingga didapat nilai k ;

$$k = 10,9988 \frac{L}{mol \cdot s} = 39595 \frac{L}{mol \cdot jam}$$

setiap kenaikan 10 °C, maka kecepatan reaksi menjadi dua kali lipatnya

$$T_1 = 334 \text{ K} \quad \rightarrow \quad k_1 = 10,9988 \frac{L}{mol \cdot s}$$

$$T_2 = 344 \text{ K} \quad \rightarrow \quad k_2 = 21,9976 \frac{\text{L}}{\text{mol.s}}$$

Persamaan Empiris Arrhenius :

$$k = Ae^{-EA/RT} \text{ atau } \ln k = \ln A + \frac{B}{T}$$

$$\ln 10,9988 = \ln A + \frac{B}{334}$$

$$\ln 21,9976 = \ln A + \frac{B}{344}$$

$$\frac{-0,6931}{-0,6931} = \frac{B \left(\frac{1}{334} - \frac{1}{344} \right)}{B \left(\frac{1}{334} - \frac{1}{344} \right)}$$

$$B = -7963,9838$$

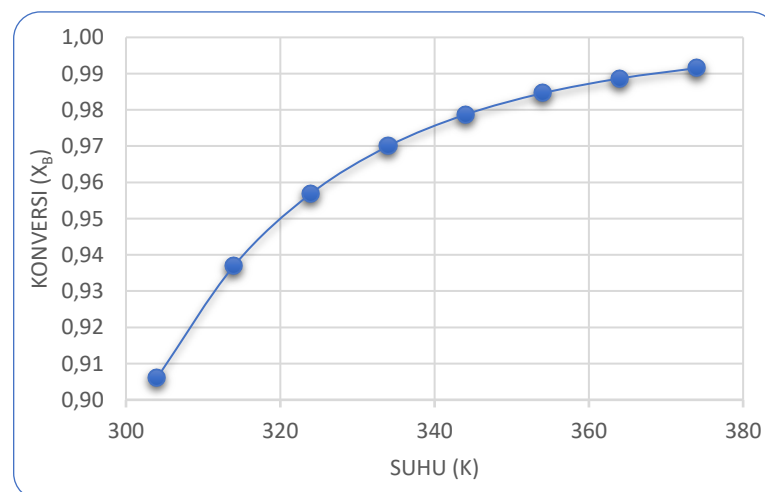
$$A = 2,4933 \times 10^{11}$$

Maka diperoleh persamaan k fungsi T :

$$k = 2,4933 \times 10^{11} e^{\frac{-7963,9838}{T}} \frac{\text{L}}{\text{mol.s}}$$

Dari rums diatas dapat dibuat hubungan antara T (K) dengan X_B

T (K)	X_B
304	0,9060
314	0,9370
324	0,9569
334	0,9700
344	0,9787
354	0,9846
364	0,9887
374	0,9915



Menentukan optimasi jumlah reaktor

1. Jumlah reaktor = 1

Diketahui :

$$F_v = 0,0278181 \text{ m}^3/\text{s}$$

$$K = 10,9987 \text{ m}^3/(\text{kmol}\cdot\text{s})$$

$$X_{A1} = 0,97$$

$$C_{A0} = 0,4899 \text{ kmol/m}^3$$

$$\begin{aligned} V &= \frac{3 \times F_v \times X_{A1}}{2 \times ((1 - X_{A1})^2) \times k \times C_{A0}} \\ &= \frac{3 \times 0,0278 \times 0,97}{2 \times ((1 - 0,97)^2) \times 10,9987 \times 0,4899} \\ &= 8,3454 \text{ m}^3 \\ &= 2204,8689 \text{ gallon} \end{aligned}$$

$$\text{Over 20\%} = 2645,843 \text{ gallon}$$

$$\begin{aligned} \text{Waktu tinggal} &= \frac{F_v}{V} \\ &= \frac{0,0278 \text{ m}^3/\text{s}}{8,3454 \text{ m}^3} \\ &= 300 \text{ detik} \\ &= 5 \text{ menit} \end{aligned}$$

2. Jumlah reaktor = 2

Diketahui :

$$F_v = 0,0278181 \text{ m}^3/\text{s}$$

$$K = 10,9987 \text{ m}^3/(\text{kmol}\cdot\text{s})$$

$$X_{A2} = 0,97$$

$$X_{A1} = 0,8268$$

$$C_{A0} = 0,4899 \text{ kmol/m}^3$$

$$V = \frac{3 \times Fv \times (X_{A2} - X_{A1})}{2 \times ((1 - X_{A2})^2) \times k \times C_{A0}}$$

$$= \frac{3 \times 0,0278 \times (0,97 - 0,826)}{2 \times ((1 - 0,97)^2) \times 10,9987 \times 0,4899}$$

$$= 1,2319 \text{ m}^3$$

$$= 325,481 \text{ gallon}$$

$$\text{over } 20\% = 390,5772 \text{ gallon}$$

$$\text{Waktu tinggal} = \frac{Fv}{V}$$

$$= \frac{0,0278 \text{ m}^3/\text{s}}{1,2319 \text{ m}^3}$$

$$= 44,2857 \text{ detik}$$

Basis Harga pada Volume 1000 Gallon = \$11000

Jumlah reaktor	Volume reaktor (gallon)	Total volume (gallon)	Harga (\$)
1	2645,843	2645,843	19721,0986
2	390,577	781,1545	12515,4615

A. Neraca Massa

Komponen	Masuk		Keluar
	Arus 1	Arus 4	Arus 5
	Kg/jam	Kg/jam	Kg/jam
C_3H_6O	3134		1291
$Ca(OCl)_2$		7015	210,4653
$CHCl_3$			3787
$Ca(C_2H_3O_2)_2$			2509
$Ca(OH)_2$			2350
H_2O	31,6642	21375	21406
$NaCl$		2505	2505
Total	34062		34062

B. Neraca Panas

Diketahui data kapasitas panas untuk masing – masing komponen :

Komponen	$C_p = A + B + CT^2 + DT^3$ (J/mol K)			
	A	B	C	D
C_3H_6O	46,878	6,27E-01	-2,08E-03	2,96E-06
$Ca(OCl)_2$	299,1	-	-	-
$CHCl_3$	28,296	6,69E-01	-2,04E-03	2,59E-06
$Ca(C_2H_3O_2)_2$	100,83	-	-	-
$Ca(OH)_2$	89,5376	-	-	-
H_2O	92,053	-400E-02	-2,11E-04	5,35E-07
$NaCl$	50	-	-	-

Menghitung neraca panas reaktor :

- Reaksi berlangsung secara isothermal
- Zat tercampur secara sempurna
- Tidak ada panas pelarutan
- *Steady state*, akumulasi = 0

Neraca Panas :

Panas Masuk + Panas Reaksi = Panas Keluar + Panas yang harus diambil pendingin

$$Q_{in} + Q_{reaksi} = Q_{out} + Q_{Pendingin}$$

➤ Panas Masuk (Q in)

$$\text{Suhu masuk} = 334 \text{ K}$$

$$\text{Suhu Referensi} = 298 \text{ K}$$

$$Q_{in} = \sum ni \int_{334}^{298} C_{pi} \cdot dT$$

$$C_p = A + B \cdot T + C \cdot T^2$$

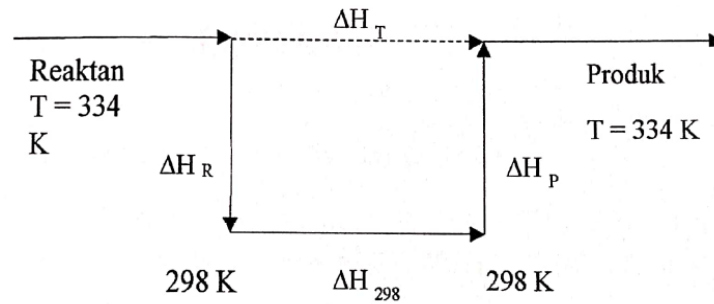
$$C_p dT = A \cdot T + \frac{B}{2 \cdot T^2} + \frac{C}{3 \cdot T^3}$$

$$C_p dT = A \cdot (T_{ref} - T_{in}) + \left(\frac{B}{2(T_{ref}^2 - T_{in}^2)} \right) + \left(\frac{C}{3(T_{ref}^3 - T_{in}^3)} \right)$$

Komponen	BM (kg/kmol)	Kg/jam	Kmol/jam	Cp (kJ/mol)	Q_{in} (kJ/Jam)
C ₃ H ₆ O	58,08	3134	53,9730	-4715	-254485
Ca(OCl) ₂	142,98	7015	49,0664	-10764	-528150
H ₂ O	18	21406	1189	-2709	-3222128
NaCl	58,44	2505,5397	42,8737	-1800	-77172
Total		34062	1335		-4081937

$$Q_{in} = -4081937 \text{ kJ/Jam}$$

➤ Panas Reaksi (Q_{Reaksi})



• Panas Reaktan (ΔH_R)

Suhu umpan masuk = 334 K

Suhu Referensi = 298 K

$$\Delta H_R = \sum \int_{334}^{298} C_{pi} \cdot dT$$

$$C_p = A + B \cdot T + C \cdot T^2$$

$$C_p dT = A \cdot T + \frac{B}{2 \cdot T^2} + \frac{C}{3 \cdot T^3}$$

$$C_p dT = A \cdot (T_{ref} - T_{in}) + \left(\frac{B}{2(T_{ref}^2 - T_{in}^2)} \right) + \left(\frac{C}{3(T_{ref}^3 - T_{in}^3)} \right)$$

Komponen	Koefisien	$C_p dT$ (kJ/kmol)	ΔH_R (kJ/kmol)
C_3H_6O	2	-4715	-9430
$Ca(OCl)_2$	3	-10764	-32292
Total			-41722

$$\Delta H_{R \text{ Total}} = -41722 \text{ kJ/kmol}$$

- Panas Produk (ΔH_P)

Suhu hasil reaksi keluar reaktor = 334 K

Suhu referensi = 298 K

$$\Delta H_P = \sum \int_{298}^{334} C_{pi} \cdot dT$$

$$C_p = A + B \cdot T + C \cdot T^2$$

$$C_p dT = A \cdot T + \frac{B}{2 \cdot T^2} + \frac{C}{3 \cdot T^3}$$

$$C_p dT = A \cdot (T_{out} - T_{ref}) + \left(\frac{B}{2(T_{out}^2 - T_{ref}^2)} \right) + \left(\frac{C}{3(T_{out}^3 - T_{ref}^3)} \right)$$

Komponen	Koefisien	Cp dT (kJ/kmol)	ΔH_P (kJ/kmol)
CHCl ₃	2	4142	8284
Ca(C ₂ H ₃ O ₂) ₂	1	3629	3629
Ca(OH) ₂	2	3223	6446
Total			18361

$$\Delta H_{P \text{ Total}} = 18361 \text{ kJ/kmol}$$

- Panas Pembentukan Standar ($\Delta H_{f 298}$)

Reaksi d reaktor :



$$\Delta H_{298} = \Sigma \Delta H_f \text{ produk} - \Sigma \Delta H_f \text{ reaktan}$$

Data energi pembentukan (ΔH_f) pada suhu 25 °C (Perry's) sebagai berikut :

$$\Delta H_f \text{ C}_3\text{H}_6\text{O} = -248,4 \text{ kJ/kmol}$$

$$\Delta H_f \text{ Ca}(\text{OCl})_2 = -1050,4 \text{ kJ/kmol}$$

$$\Delta H_f \text{ CHCl}_3 = -134,1 \text{ kJ/kmol}$$

$$\Delta H_f \text{ Ca}(\text{C}_2\text{H}_3\text{O}_2)_2 = -1523,3944 \text{ kJ/kmol}$$

$$\Delta H_f \text{ Ca}(\text{OH})_2 = -985,667 \text{ kJ/kmol}$$

$$\Delta H_f \text{ reaktan} = 2 (-1050,4 \text{ kJ/kmol}) + 3 (-248,4 \text{ kJ/kmol}) = -3648000 \text{ kJ/kmol}$$

$$\Delta H_f \text{ produk} = 2 (-134,1 \text{ kJ/kmol}) + (-1523,3944 \text{ kJ/kmol}) + 2 (-985,667 \text{ kJ/kmol})$$

$$= -3762928,4 \text{ kJ/kmol}$$

$$\Delta H_f 298 = \Sigma \Delta H_f \text{ produk} - \Sigma \Delta H_f \text{ reaktan}$$

$$= (-3762928,4 \text{ kJ/kmol}) - (-3648000 \text{ kJ/kmol}) = -114928,4 \text{ kJ/kmol}$$

$$\Delta H_f \text{ reaksi} = \Delta H_R + \Delta H_P + \Delta H_f 298$$

$$= (-41722,0998) + (18361,5030) + (-114928,4) = -138288,9967 \text{ kJ/kmol}$$

$$\begin{aligned}
 Q_{\text{Reaksi}} &= \Delta H_{\text{Reaksi}} \cdot n_{B0} \cdot X_B \\
 &= (-138288,9967 \text{ kJ/kmol}) \times (49,0664 \text{ kmol/jam}) \times (0,97) \\
 &= -6581780,3302 \text{ kJ/jam}
 \end{aligned}$$

➤ Panas Keluar (Q_{out})

$$\text{Suhu masuk} = 334 \text{ K}$$

$$\text{Suhu keluar} = 298 \text{ K}$$

$$Q_{\text{out}} = \sum ni \int_{334}^{298} C_{pi} \cdot dT$$

$$C_p = A + B \cdot T + C \cdot T^2$$

$$C_p dT = A \cdot T + \frac{B}{2 \cdot T^2} + \frac{C}{3 \cdot T^3}$$

$$C_p dT = A \cdot (T_{\text{ref}} - T_{\text{in}}) + \left(\frac{B}{2(T_{\text{ref}}^2 - T_{\text{in}}^2)} \right) + \left(\frac{C}{3(T_{\text{ref}}^3 - T_{\text{in}}^3)} \right)$$

Komponen	BM (kg/kmol)	Kg/jam	Kmol/jam	Cp (kJ/mol)	Q_{out} (kJ/Jam)
C ₃ H ₆ O	58,08	1291	22,2434	-4715	-104878
Ca(OCl) ₂	142,98	210,4653	1,4720	-10764	-15844
CHCl ₃	119,38	3787	31,7296	-4142	-131438
Ca(C ₂ H ₃ O ₂) ₂	158,17	2509	15,8648	-3629	-57587
Ca(OH) ₂	74,093	2350	31,7296	-3223	-102275
H ₂ O	18	21406	1189	-2709	-3222128
NaCl	58,44	2505	42,8737	-1800	-77172
Total		34062	1335		-3711326

$$Q_{\text{out}} = -3711326 \text{ kJ/jam}$$

Panas yang harus diambil pendingin :

$$Q_{\text{in}} + Q_{\text{reaksi}} = Q_{\text{out}} + Q_{\text{pendingin}}$$

$$Q_{\text{pendingin}} = Q_{\text{in}} + Q_{\text{reaksi}} - Q_{\text{out}}$$

$$= (-4081937 \text{ kJ/Jam}) + (-6581780 \text{ kJ/jam}) - (-3711326 \text{ kJ/jam})$$

$$= -6925391 \text{ kJ/jam}$$

Masuk		Keluar	
Komponen	kJ/jam	Komponen	kJ/jam
Panas Umpan Masuk Reaktor (Q_{in})	-4081937	Panas hasil reaksi Reaktor (Q_{out})	-3711326
Panas reaksi pada suhu 61 °C (Q_{reaksi})	-6581780	Panas diserap pendingin ($Q_{pendingin}$)	-6952391
Total	-10663717	Total	-10663717

C. Dimensi Reaktor

1. Diameter

Volume Cairan

Volume cairan dalam reaktor

$$V_{cairan} = \frac{3 \cdot F_V \cdot X_B}{2 \cdot k \cdot C_{B0} (1 - X_B)^2}$$

$$V_{cairan} = \frac{3 \cdot 0,0278 \frac{m^3}{s} \cdot 0,97}{2 \cdot 10,9988 \frac{L}{mol \cdot s} \cdot 0,4900 \frac{mol}{L} \cdot (1 - 0,97)^2}$$

$$V_{cairan} = 8,3454 m^3 = 2204 \text{ gallon} = 52,4912 \text{ bbl}$$

$$\theta = \frac{V_{cairan}}{F_V} = \frac{m^3}{\frac{m^3}{s}} = 300 \text{ detik}$$

$$\text{Over Design} = 20 \% \text{ (Faktor Keselamatan)}$$

$$V_{reaktor} = 1,2 \times V_{cairan}$$

$$= 1,2 \times 8,3454 \text{ m}^3$$

$$= 10,0145 \text{ m}^3 = 2645 \text{ gallon}$$

Dari silla, “standar Stirres Reaktors” tabel 7.3 hal 383. Diperoleh diameter dan tinggi reaktor berdasarkan kapasitas volume. Untuk volume reaktor 2645,8428 gallon dengan maksimum kapasitas 2756 gallon, dipilih :

$$\text{OD} \quad = 84 \text{ in} \quad = 2,1336 \text{ m}$$

$$\text{H} \quad = 105 \text{ in} \quad = 2,6670 \text{ m}$$

2. Tebal shell

Diasumsikan tebal shell = 0,25 in

Diameter dalam (ID) : $\text{OD} - 2 \times t$

$$: 84 - 2 (0,25) = 83,5 \text{ in}$$

Tekanan operasi : 2 atm (29,4 psia)

Suhu operasi : 61 °C (141,8 °F)

Bahan konstruksi : Stainless steel SA 167 tipe 304 A. (Brownell and Young, hal 342). Pertimbangan pemilihan bahan, bahan memiliki tegangan maksimal (f) = 18.750 psi pada $T = 156,2$ °F. Jenis sambungan yang dipakai adalah *double welded butt joint* dengan efisiensi sambungan $E = 80$ %. Faktor korosi (C) untuk stainless steel = 0,125 in (Peters, M.S., K.D., Timmerhaus, Plant Design and Economics for Chemical Engineers”, ed V).

Tekanan reaktor $P = 2 \text{ atm} = 29,4 \text{ psia}$

Tebal shell dihitung dengan persamaan 13.1 (Brownell and Young, hal 258) :

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

$$t = \frac{29,4 \text{ psia } (41,75 \text{ in})}{18750 \text{ psia } (0,8) - 0,6 (29,4 \text{ psia})} + 0,125 \text{ in}$$

$$t = 0,2069 \text{ in}$$

Dipakai tebal shell standar, $t = \dots$ in (Brownell and Young, hal 89)

Maka asumsi tebal awal benar. Kesimpulan :

$$\text{ID} = 83,5 \text{ in}$$

$$\text{OD} = 84 \text{ in}$$

$$t = 0,25 \text{ in}$$

3. Tebal head (dasar)

Pemilihan head berdasar tekanan operasi, reaktor beroperasi pada tekanan 2 atm = 29,4 psia. Jenis tutup yang dipilih adalah *torispherical dished head* karena memiliki range sebesar 15-200 psig (Brownell and Young, hal 88). Bahan konstruksi yang digunakan adalah tipe Stainless steel SA 167 tipe 304 A. (Brownell and Young, hal 342). Tegangan maksimal yang diijinkan untuk bahan ini (*fall*) = 18.750 psia. Jenis sambungan yang dipakai adalah *double welded butt joint* dengan efisiensi sambungan $E = 80 \%$. Faktor korosi (C)

untuk stainless steel = 0,125 in (Peters, M.S., K.D., Timmerhaus, Plant Design and Economics for Chemical Engineers”, ed V).

Tekanan reaktor $P = 2 \text{ atm} = 29,4 \text{ psia}$

Tebal shell dihitung dengan persamaan 13.1 (Brownell and Young, hal 258)

$$t = \frac{0,885 P r}{f E - 0,1 P} + C$$

Dari tabel 5.7 Brownell-Young untuk OD = 84 in : $i_{cr} = 5,125 \text{ in}$

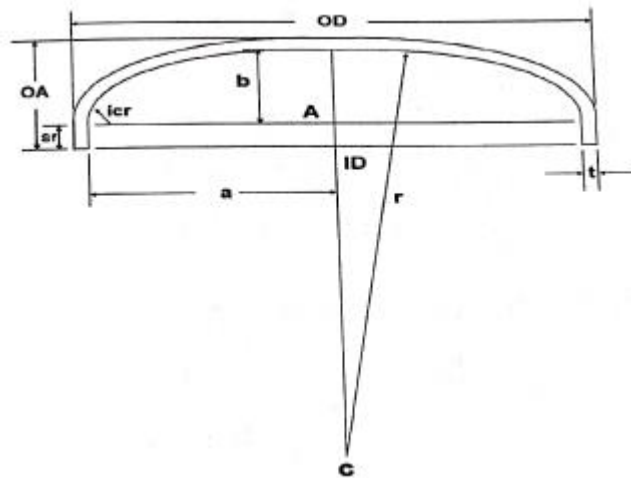
$$r = 84 \text{ in}$$

$$t = \frac{0,885 (29,4 \text{ psia}) (84 \text{ in})}{18750 \text{ psia} (0,8) - 0,1 (29,4 \text{ psia})} + 0,125 \text{ in}$$

$$t = 0,2707 \text{ in}$$

Dipakai tebal head standar, $t = 0,3125 \text{ in}$ (Brownell and Young, hal 89)

4. Tinggi Head



Keterangan :

Icr : Inside-Corner Radius

Sf : Straight Flange

r : Radius of Dish

b : Depth of Dish (Inside)

a : Inside Radius

ID : Inside Diameter

Dari tabel 5.6 Brownell and Young, straight flange antara 1,5-3 in untuk tebal 0,375 in.

Dipilih straight flange (Sf) = 2 in = 0,1667 ft = 0,0508 m

$$a = \frac{ID}{2} = \frac{83,5}{2} = 41,75 \text{ in}$$

$$AB = a - icr$$

$$= 41,75 - 5,125 = 36,625 \text{ in}$$

$$BC = r - icr$$

$$= 84 - 5,125 = 78,875 \text{ in}$$

$$\begin{aligned}
 AC &= \sqrt{BC^2 - AB^2} \\
 &= \sqrt{(78,875)^2 - (36,625)^2} \\
 &= 69,8561 \text{ in}
 \end{aligned}$$

$$\begin{aligned}
 b &= r - AC \\
 &= 84 - 69,8561 \\
 &= 14,1439 \text{ in}
 \end{aligned}$$

$$\begin{aligned}
 OA &= b + sf + t \text{ head} \\
 &= 14,1439 + 2 + 0,3125 \\
 &= 16,4564 \text{ in} = 1,3714 \text{ ft} = 0,4180 \text{ m}
 \end{aligned}$$

Jadi tinggi head (H_{head}) = 0,4180 m

5. Volume Cairan dalam Head

$$\begin{aligned}
 V_{\text{head}} &= 0,000049 D^3 + \frac{\pi D^2 sf}{4} \\
 &= 0,000049 \left(\frac{83,5}{12} \text{ ft}\right)^3 + \frac{3,14 \cdot (83,5 \text{ ft})^2 \cdot 0,16667 \text{ ft}}{4} \\
 &= 34,8675 \text{ ft}^3 = 0,9867 \text{ m}^3
 \end{aligned}$$

6. Tinggi Cairan dalam shell

Luas penampang reaktor :

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

$$A = \frac{3,14}{4} (2,1209)^2 = 3,5343 \text{ m}^2$$

Volume head bawah :

$$\text{Volume head} = 0,9867 \text{ m}^3$$

$$\text{Volume larutan dalam reaktor} = 8,3454 \text{ m}^3$$

$$\begin{aligned} \text{Volume larutan dalam shell} &= \text{vol. larutan} - \text{vol. head bawah} \\ &= 8,3454 - 0,9867 = 7,3587 \text{ m}^3 \end{aligned}$$

$$\text{Tinggi larutan dalam bagian shell} = \frac{\text{Volume larutan}}{\text{luas penampang}}$$

$$H_{\text{liquid shell}} = \frac{7,3587 \text{ m}^3}{3,5343 \text{ m}^3} = 2,0820 \text{ m}$$

7. Tinggi Reaktor

$$\begin{aligned} \text{Tinggi Reaktor} &= H_{\text{shell}} + 2 (H_{\text{head}}) \\ &= 2,6670 \text{ m} + 2 (0,4180) \text{ m} \\ &= 3,5030 \text{ m} \end{aligned}$$

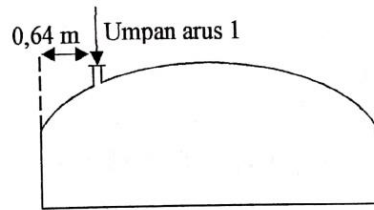
D. Perancangan Pipa

1. Ukuran Pipa Pemasukan Aseton (umpan arus 1)

Komponen	Kg/Jam	Kg/m ³	m ³ /Jam
C ₃ H ₆ O	3134	742,318	4,2229
H ₂ O	31,3475	994,0067	0,0318
Total	3166	1736	4,2547

- Luas pipa pemasukan umpan arus 1 (A_{pipa})

$$\begin{aligned} \text{Posisi pipa umpan arus 1} &= 0,3 \times \text{OD} \\ &= 0,3 \times 84 \text{ in} \\ &= 25,2 \text{ in} = 0,6400 \text{ m} \end{aligned}$$



$$Q \text{ umpan arus 1} = 4,255 \text{ m}^3/\text{jam}$$

$$A_{\text{pipa}} = \frac{Q_{\text{umpan}}}{\text{Kecepatan linier umpan}}$$

Menurut Schweitzer, kecepatan linear umpan disyaratkan 0,6096 – 1 m/s.

Diambil kecepatan linear umpan 1 m/detik.

$$A_{\text{pipa}} = \frac{4,255 \text{ m}^3/\text{jam}}{1 \text{ m/s}} \times \frac{1 \text{ jam}}{3600 \text{ s}} = 0,00118 \text{ m}^2$$

- Menghitung diameter dalam pipa (ID)

$$ID = \left(\frac{4 \times A_{\text{pipa}}}{\pi} \right)^{0,5}$$

$$ID = \left(\frac{4 \times 0,00118 \text{ m}^2}{3,14} \right)^{0,5} = 0,03 \text{ m} \times \frac{1 \text{ in}}{0,0254 \text{ m}} = 1,195 \text{ in}$$

Berdasarkan ID yang telah dihitung, dipilih ukuran pipa standar dari Tabel

11. Kern, D.Q. halaman 844 sebagai berikut :

$$\text{Nominal pipe size (Nps)} = 1,25 \text{ in}$$

$$\text{Schedule Number (Sch)} = 40$$

Outside Diameter (OD) = 1,66 in

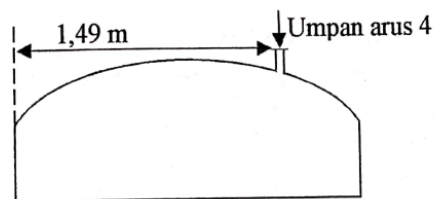
Inside diameter (ID) = 1,38 in

2. Ukuran pipa pemasukan kalsium hipoklorit (umpan arus 4)

Komponen	Kg/jam	Kg/m ³	m ³ /jam
Ca(OCl) ₂	7015,5111	2350	2,9853
NaCl	2505,5396	2165	1,1572
H ₂ O	91229,5448	994,0066	91,7796
Total	100750,5956		95,9222

- Luas pipa pemasukan umpan rus 4 (A_{pipa})

$$\begin{aligned} \text{Luas pipa umpan arus 4} &= 0,7 \times \text{OD} \\ &= 0,7 \times 84 \text{ in} \\ &= 58,8 \text{ in} = 1,4935 \text{ m} \end{aligned}$$



$$Q \text{ umpan arus 4} = 95,8903 \text{ m}^3/\text{jam}$$

$$A_{\text{pipa}} = \frac{Q \text{ umpan}}{\text{kecepatan linear umpan}}$$

Menurut Schweitzer, kecepatan linear umpan disyaratkan 0,6096 – 1 m/s.

Diambil kecepatan linear umpan 1 m/detik.

$$A_{\text{pipa}} = \frac{95,8903 \text{ m}^3/\text{jam}}{1 \text{ m/s}} \times \frac{1 \text{ jam}}{3600 \text{ s}} = 0,0266 \text{ m}^2$$

- Menghitung diameter dalam pipa (ID)

$$ID = \left(\frac{4 \cdot A_{\text{pipa}}}{\pi} \right)^{0,5}$$

$$ID = \left(\frac{4 \cdot 0,0266 \text{ m}^2}{3,14} \right)^{0,5} = 0,1441 \text{ m} = \frac{1 \text{ in}}{0,0254 \text{ m}} = 5,6765 \text{ in}$$

Berdasarkan ID yang telah dihitung, dipilih ukuran pipa standar dari Tabel

11. Kern, D.Q. halaman 844 sebagai berikut :

Nominal pipe size (Nps) = 6 in

Schedule Number (Sch) = 40

Outside Diameter (OD) = 6,625 in

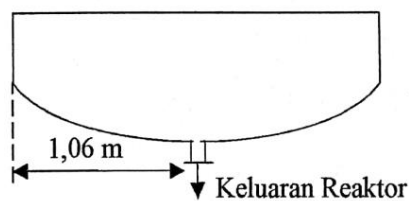
Inside Diameter (ID) = 6,065 in

3. Ukuran Pipa Pengeluaran Reaktor

Komponen	Kg/Jam	Kg/m ³	m ³ /Jam
C ₃ H ₆ O	1291	742,3180	1,7403
Ca(OCl) ₂	210,4653	2350	0,0895
CHCl ₃	3787	1407	2,6904
Ca(C ₂ H ₃ O ₂) ₂	2509	1509	1,6629
Ca(OH) ₂	2350	2211	1,0631
H ₂ O	91229	994,0066	91,7796
NaCl	2505	2165	1,1572
Total	103885		100,1833

- Luas pipa pengeluaran hasil arus 5 (A_{pipa})

$$\begin{aligned}
 \text{Posisi pipa keluar reaktor} &= 0,5 \times \text{OD} \\
 &= 0,5 \times 84 \text{ in} \\
 &= 42 \text{ in} = 1,0668 \text{ m}
 \end{aligned}$$



$$Q \text{ keluaran reaktor} = 100,1833 \text{ m}^3/\text{jam}$$

Menurut Schweitzer, kecepatan linear umpan disyaratkan 0,6096 - 1 m/s.

Diambil kecepatan linear 1 m/detik.

$$A_{\text{pipa}} = \frac{100,1833 \text{ m}^3/\text{jam}}{1 \text{ m/s}} \times \frac{1 \text{ jam}}{3600 \text{ s}} = 0,0278 \text{ m}^2$$

- Menghitung diameter dalam pipa (ID)

$$ID = \left(\frac{4 \cdot A_{\text{pipa}}}{\pi} \right)^{0,5}$$

$$ID = \left(\frac{4 \cdot 0,0278 \text{ m}^2}{3,14} \right)^{0,5} = 0,1473 \text{ m} = \frac{1 \text{ in}}{0,0254 \text{ m}} = 5,8022 \text{ in}$$

Berdasarkan ID yang telah dihitung, dipilih ukuran pipa standar dari table

11. Kern, D.Q. halaman 844 sebagai berikut :

Nominal Pipe Size (Nps) = 6 in

Schedule Number (Sch) = 40

Outside Diameter (OD) = 6,625 in

Inside Diameter (ID) = 6,065 in

E. Perancangan Pengaduk Reaktor

Data viskositas masing-masing komponen

$$T = 344\text{K}$$

$$\text{Log } \mu = A + B/T + CT + DT^2 \text{ (cP)}$$

Ca(OCl)₂, Ca(C₂H₃O₂)₂, NaCl terlarut sempurna dalam air sehingga viskositas (cP) mengikuti nilai cP dari H₂O

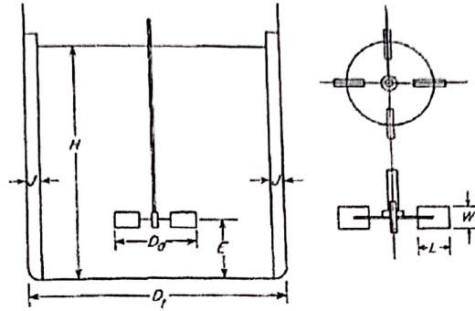
Komponen	A	B	C	D
C ₃ H ₆ O	-7,2126	903,05	0,018385	-0,000020353
CHCl ₃	-4,7831	699,02	0,0100929	-0,000012244
Ca(OH) ₂	0,0128			
H ₂ O	-10,2158	1792,5	0,01773	-0,000012631

Komponen	F Keluar (Kg/Jam)	x	μ (cP)	x.μ
C ₃ H ₆ O	1291	0,0124	0,2297	0,0028
Ca(OCl) ₂	210,4653	0,0020	0,4610	0,0009
CHCl ₃	3787	0,0364	0,2064	0,0075
Ca(C ₂ H ₃ O ₂) ₂	2509	0,0241	0,4610	0,0111
Ca(OH) ₂	2350	0,0226	1,03	0,0233
H ₂ O	91229	0,8781	0,4610	0,4048
NaCl	2505	0,0241	0,4610	0,0111
Total	103885	1		0,4617

Didapatkan viskositas rata-rata sebesar $0,461741 \text{ cP} = 0,000462 \text{ kg/m.s}$

Pada fig.8-1 Rasel H.F. dengan memasukkan viskositas dan adanya produk padatan dipilih *mixing service* berupa “*solid suspension*” sehingga didapat pengaduk menggunakan *Flat Blade Turbine* dengan perbandingan diameter

dalam reaktor dengan *impeller* diameter sebesar 2:1 sampai 3,5:1 sedangkan wales untk standar turbin design digunakan 4 buah baffle dan 6 buah blade.



Dimana :

D_a = diameter pengaduk

D_t = diameter reaktor (diameter dalam)

W = tinggi blade

J = Lebar Baffle

H = Tinggi shell

E = jarak pengaduk dari dasar reaktor

L = Panjang blade

(Mc Cabe and Smith, 1993)

Perhitungan dimensi pengaduk

$$\frac{Da}{Dt} = \frac{1}{3}$$

$$\frac{E}{Dt} = \frac{1}{3}$$

$$\frac{W}{Da} = \frac{1}{5}$$

$$\frac{J}{Dt} = \frac{1}{12}$$

$$\frac{L}{Da} = \frac{1}{4}$$

Dengan $Dt = ID = 83,5 \text{ in} = 2,1209 \text{ m}$

$$Da = \frac{2,1209 \text{ m}}{3} = 0,7069 \text{ m} = 27,8333 \text{ in}$$

$$E = \frac{2,1209 \text{ m}}{3} = 0,7069 \text{ m} = 27,8333 \text{ in}$$

$$W = \frac{0,7069 \text{ m}}{5} = 0,14138 \text{ m} = 5,5666 \text{ in}$$

$$J = \frac{2,1209 \text{ m}}{12} = 0,1767 \text{ m} = 6,9583 \text{ in}$$

$$L = \frac{0,7069 \text{ m}}{4} = 0,1767 \text{ m} = 6,9583 \text{ in}$$

(Mc Cabe and Smith, 1997)

Volume Baffle (V_{baffle})

Volume Baffle = Tinggi shell – Jarak pengaduk dari dasar shell

$$= 105 - 27,8333$$

$$= 77,1666 \text{ in}$$

Tebal Baffle Standar = 0,0079 m = 0,3110 in

V_{baffle} = lebar baffle x Panjang baffle x tebal baffle x jumlah baffle

$$= 6,9583 \times 77,1663 \times 0,3110 \times 4$$

$$= 668,0182 \text{ in}^3 = 0,0109 \text{ m}^3$$

Jumlah Pengaduk

$$\text{Jumlah pengaduk} = \frac{WELH}{ID} \quad (\text{pers, 8.9 – Rase, 1977})$$

dengan,

WELH = *water equivalent liquid high* = $Z_1 \cdot sg$

ID = diameter dalam reaktor, in

S_g = specific gravity

Z_1 = tinggi cairan pada bagian shell + tinggi head

Z_1 = tinggi cairan pada bagian shell + sf + b

$$= 98,1150 \text{ in}$$

$$\rho \text{ campuran} = \frac{Fv}{W} = \frac{103885}{83,5} = 1244 \text{ kg/m}^3$$

$$s_g = \frac{\rho \text{ campuran}}{\rho \text{ air } 61C} = \frac{1244}{994,0067} = 1,2516$$

$$WELH = 102,3541 \text{ in}$$

$$\text{Jumlah pengaduk} = \frac{WELH}{ID} = \frac{102,3541}{83,5} = 1,225 \text{ in}$$

Putaran pengaduk

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

$$= \frac{600 \text{ ft/menit}}{\pi \left(\frac{27,8333}{12}\right) \text{ ft}} \sqrt{\frac{102,3541 \text{ in}}{2 (27,8333 \text{ in})}} = 111,7103 \text{ rpm}$$

Diambil kecepatan standar:

$$N = 100 \text{ rpm} = 1,6667 \text{ putaran/detik} \quad (\text{Walas p.288, 1990})$$

Cek nilai N :

Range N_p untuk turbine $N_p = 600- 1200$

(tabel 8.2 – Rase)

$$\begin{aligned}
 N_p &= N \times \pi \times D_i\text{-dalam ft} \\
 &= 100 \times \pi \times 2,3159 \\
 &= 727,8769 \text{ rpm (masuk kisaran, aman)}
 \end{aligned}$$

Bilangan Reynold

$$N_{Rc} = \frac{D_i^2 \cdot N \cdot \rho}{\mu m} \quad (\text{hal 354 – Ras, 1997})$$

Dengan :

ρ = rapat massa campuran, kg/m^3

N = kecepatan pengadukan, putaran/detik

D_i = diameter impeller, m

μ = viskositas campuran, $\text{kg/m}\cdot\text{detik}$

$$N_{Rc} = \frac{(0,7069 \text{ m})^2 \cdot (1,6667 \frac{\text{putaran}}{\text{detik}}) \cdot (1036,9524 \frac{\text{kg}}{\text{m}^3})}{0,0004617 \frac{\text{kg}}{\text{m}\cdot\text{s}}} = 1870712,926$$

Dari fig 10.6 Wallas “*Chemical Process Equipment*” halaman 292. Dipilih curve 4 didapat N_p sebesar 2,4.

$$N_p = 2,4$$

Power pengaduk :

Dihitung menggunakan persamaan :

$$P_0 = N_p \cdot \rho \cdot N^3 \cdot D_i^5$$

Dimana :

$$P_0 = \text{Daya Penggerak}$$

$$N_p = \text{Bilangan Daya}$$

$$\rho = \text{Densitas Fluida}$$

$$N = \text{Kecepatan Putaran}$$

$$D_i = \text{Diameter Pengaduk}$$

$$P_0 = N_p \cdot \rho \cdot N^3 \cdot D_i^5$$

$$= (2,4) (1036,9524) (1,6667)^3 (0,7069)^5$$

$$= 2034,7498 \text{ kg.m}^2/\text{s}^3 = \text{N m/s} = \text{J/s}$$

$$= 2,7286 \text{ Hp}$$

Dari tabel 3.1 Towler and Sinnott diperoleh efisiensi untuk daya sebesar 2543

watt adalah 83%.

$$\text{Tenaga motor untuk pengaduk} = \frac{P_o}{\text{Efisiensi}} = \frac{2,7286 \text{ Hp}}{0,83} = 3,4108 \text{ Hp}$$

Pemilihan motor standar merujuk dari Ludwig, E.E, “*Applied Process Design for Chemical and Petrochemical Plants*”, Gulf Publishing, Co.

Huston, Texas (2001). Dipilih motor standar yang digunakan adalah motor induksi dengan daya 5 Hp.

Beban hidraulik (σ)

$$\sigma = P_0 / N$$

Dimana :

σ = beban hidraulik (N.m)

N = kecepatan putar (rps)

P_0 = daya penggerak (N.m/s)

$$\Sigma = \frac{2034 \text{ N} \cdot \frac{\text{m}}{\text{s}}}{1,6667 \text{ rps}} = 1220 \text{ N} \cdot \text{m}$$

Momen bending (M)

$$M = \frac{0,3 \cdot P_0 \cdot L_P}{N \cdot L}$$

Dimana :

M = momen bending

L_p = Panjang poros (m)

L = Panjang impeller (m)

Diketahui :

$$\begin{aligned} L_p &= (H_{\text{head}} + H_{\text{shell}}) - (1/3 \times H_{\text{shell}}) \\ &= (b + sf + H_{\text{shell}}) - (1/3 \times H_{\text{shell}}) \\ &= (14,1438 + 2 + 105) - (1/3 \times 105) \\ &= 86,1438 \text{ in} = 2,188 \text{ m} \end{aligned}$$

$$M = \frac{0,3 \cdot 2034 \cdot 2,188}{1,6667 \cdot 6,9583} = 4534 \text{ N.m}$$

Diameter poros (D_{shaft})

$$D_{\text{shaft}} = \left(\frac{16 \times (\sigma^2 + M^2)^{0,5}}{\pi \times f} \right)^{\frac{1}{3}}$$

$$f \text{ (Allowable Stress)} = 18750 \text{ psi} = 127551020 \text{ N/m}^2$$

$$D_{\text{shaft}} = \left(\frac{16 \times (1220^2 + 4534^2)^{0,5}}{3,14 \times 127551020} \right)^{\frac{1}{3}} = 0,0572 \text{ m}$$

Volume poros (V_{shaft})

$$\begin{aligned} V_{\text{shaft}} &= \pi \cdot D_{\text{shaft}}^2 \cdot L_p \\ &= 3,14 \times 0,0572^2 \times 2,188 \\ &= 0,0225 \text{ m}^3 \end{aligned}$$

Volume impeller (V_{impeller})

$$\text{Jumlah impeller} = 4$$

$$\text{Jumlah sudu (n)} = 6$$

$$\text{Tinggi blade (W)} = 5,5583 \text{ in}$$

$$\text{Panjang blade (L)} = 6,9479 \text{ in}$$

$$\text{Tebal impeller (t}_i\text{)} = 1/5 \text{ in} = 0,2 \text{ in}$$

$$\begin{aligned}
 V_{\text{impeller}} &= 4 \cdot L \cdot W \cdot t_i \cdot n \\
 &= (4) \cdot (6,9479 \text{ in}) \cdot (5,5583 \text{ in}) \cdot (0,2 \text{ in}) \cdot (6) \\
 &= 185,3704 \text{ in}^3 = 0,003038 \text{ m}^3
 \end{aligned}$$

Volume pengaduk (V_A)

$$\begin{aligned}
 V_A &= V_{\text{shaft}} + V_{\text{impeller}} \\
 &= 0,0225 \text{ m}^3 + 0,003038 \text{ m}^3 \\
 &= 0,0252538 \text{ m}^3
 \end{aligned}$$

F. Perancangan Pendingin

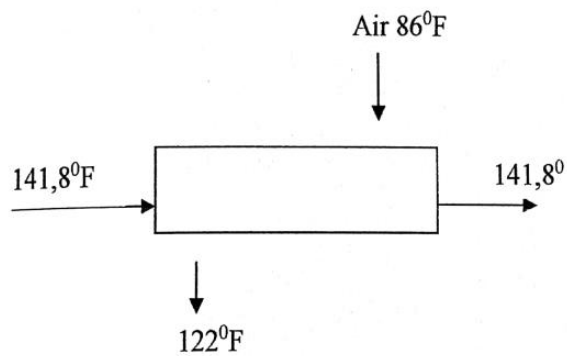
Fungsi : mempertahankan suhu dalam reaktor tetap $61^{\circ} \text{C} = 334\text{K} = 141,8^{\circ} \text{F}$.

Pendingin yang digunakan adalah air.

Suhu masuk : $30^{\circ} \text{C} = 303\text{K} = 86^{\circ} \text{F}$

Suhu keluar : $50^{\circ} \text{C} = 323\text{K} = 122^{\circ} \text{F}$

$$\begin{aligned}
 \text{Panas yang harus ditransfer (Q)} &= 6952391 \text{ kJ/jam} \\
 &= 6589594 \text{ BTU/jam} \\
 &= 1931 \text{ kJ/s}
 \end{aligned}$$



Beban panas yang harus diambil :

$$Q : U_D \cdot A \cdot \Delta T_{LMTD}$$

Q : beban panas yang harus diambil

U_D : overall design coefisien of heat transfer (BTU/jam ft^2 °F)

LMTD = Logaritma rata-rata beda temperature °F

$$\begin{aligned}
 LMTD &= \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln \frac{(T_1 - t_2)}{(T_2 - t_1)}} = \frac{(141,8 - 86) - (141,8 - 122)}{\ln \frac{(141,8 - 86)}{(141,8 - 122)}} \\
 &= 34,7459F
 \end{aligned}$$

Pemilihan Ud

Dari tabel 8, p-840 kern “*Process Heat Transfer*” untuk *aqueous solution (hot fluid) and water (cold fluid)*

$$U_D = 250 - 650 \text{ Btu/jam. Ft}^2 \cdot ^\circ\text{F}$$

$$\text{Diambil } U_D = 639 \text{ Btu/jam.ft}^2 \cdot ^\circ\text{F}$$

Luas permukaan transfer panas :

$$A = \frac{Q}{U_d \times \Delta T_{LMTD}}$$

$$A = \frac{6589594 \text{ BTU/jam}}{639 \frac{\text{BTU}}{\text{jam.ft}^2 \cdot ^\circ\text{F}} \times 34,7459^\circ\text{F}} = 2247,3275 \text{ ft}^2$$

Dari Silla Tabel 7.3 dipilih Standar Stirred Reaktor dengan volume 2756 Gallon didapat luas jaket sebesar 230 ft². Karena luas transfer panas beban > luas transfer panas jaket tangka reaktor, maka pendingin yang digunakan berbentuk coil.

Kebutuhan air pendingin

$$W_a = Q / c_p \cdot \Delta T$$

Dengan :

Q = jumlah panas yang diserap = 6952391 kJ/jam

Cp = panas jenis pendingin pada suhu rata-rata 313K

$$= 75,2692$$

ΔT = beda suhu pendingin = 20 K

$$W_a = \frac{6952391}{75,2692 \times 20} = 4618 \text{ kmol/jam}$$

$$= 83130 \text{ kg/jam}$$

$$= 23,0917 \text{ kg/s}$$

$$= 50,9085 \text{ lb/s}$$

Kecepatan Volumetrik Pendingin

$$G = \frac{W}{\rho} = \frac{83130 \text{ kg/jam}}{1013 \text{ kg/m}^3} \times \frac{1 \text{ jam}}{3600 \text{ detik}} = 0,02277 \text{ m}^3/\text{detik}$$

Perancangan Pipa Coil

Fluida yang dilewatkan didalam coil adalah air. Menurut Ludwig, vol 3 ed 2nd hal 85, karena viskositas air = 0,6654 cP (lebih kecil dari 1 cP).

Ukran pipa standar dari tabel 11 kern,D.Q. halaman 844 diambil :

$$\text{Nominal pipe size (Nps)} = 6 \text{ in}$$

$$\text{Schedule Number (Sch)} = 40$$

$$\text{Outside Diameter (OD)} = 6,625 \text{ in} = 0,5521 \text{ ft} = 0,1683 \text{ m}$$

$$\text{Inside pipe (ID)} = 6,065 \text{ in} = 0,5054 \text{ ft} = 0,1540 \text{ m}$$

$$\text{Flow area per pipe (At)} = 28,9 \text{ in}^2 = 0,2007 \text{ ft}^2 = 0,0186 \text{ m}^2$$

$$\text{At}' = 1,734 \text{ ft}^2/\text{ft} = 0,1611 \text{ m}^2/\text{m}$$

Berdasarkan ukuran ID_{coil} , makadapat disesuaikan

$$G_{\text{water}} = W_a/\text{At}$$

$$= \frac{50,9085 \frac{\text{lb}}{\text{s}} \times \frac{3600 \text{ s}}{1 \text{ jam}}}{0,2007 \text{ ft}^2} = 913157 \frac{\text{lb}}{\text{jam ft}^2}$$

$$Re = \frac{G_{\text{water}} \times ID}{\mu_{\text{water}}} = \frac{913157 \frac{\text{lb}}{\text{jam ft}^2} \times 0,5054 \text{ ft}}{1,6768 \frac{\text{lb}}{\text{ft jam}}} = 275231$$

Dari fig. 24 Kern, diperoleh $j_h = 800$

$$hi = jH \cdot \left[\frac{k}{D} \right] \cdot \left[\frac{Cp \cdot \mu_w}{k} \right]^{0,33} \cdot \left[\frac{\mu}{\mu_w} \right]^{0,14}$$

Dengan :

Hi = koefisien transfer panas cairan (BTU/ft².jam.⁰F)

D = diameter coil = 4,175 ft

$$K = \text{konduktivitas panas} = 1,6955 \text{ BTU/jam ft}^3 \text{ F}$$

$$cP = \text{panas jenis} = 0,9117 \text{ BTU/lb.F}$$

$$\mu = \text{viskositas cairan} = 0,4617 \text{ lb/ ft jam}$$

$$\mu_w = \text{viskositas pendingin} = 1,1635 \text{ lb/ft jam}$$

$$hi = 800 \times \frac{1,6955}{4,175} \left(\frac{0,9117 \times 1,1635}{1,6955} \right)^{1/3} \times \left(\frac{0,4617}{1,1635} \right)^{0,14}$$

$$hi = 1879397 \frac{\text{BTU}}{\text{jam. ft. F}}$$

$$D_{\text{coil}} = 0,5 D_i - W + 0,5 D_p$$

$$D_{\text{coil}} = 0,5 (2,1209 \text{ m}) - (0,14138) + 0,5 (0,706966667 \text{ m})$$

$$= 1,27254 \text{ m} = 4,175 \text{ ft} = 50,1 \text{ in}$$

$$h_{io} = h_i (1 + 3,5 ID_{\text{coil}}/D_{\text{coil}}) \text{ Kern hal. 721}$$

$$= 1879397 \frac{\text{BTU}}{\text{jam ft}^2 \text{ F}} \left(1 + 3,5 \frac{4,175 \text{ ft}}{4,175 \text{ ft}} \right) = 2675 \frac{\text{BTU}}{\text{jam ft F}}$$

$$\text{Nrc dalam reaktor} = 1870712$$

Dari fig.20.2 Kern, diperoleh $j_h = 4600$

$$h_i = jH \cdot \left[\frac{k}{D} \right] \cdot \left[\frac{C_p \cdot \mu_w}{k} \right]^{0,33} \cdot \left[\frac{\mu}{\mu_w} \right]^{0,14}$$

Dengan :

h_o = koefisien transfer panas cairan (BTU/ft².jam.⁰F)

D = diameter reaktor = 6,9583 ft

k = konduktivitas panas = 1,6955 BTU/jam ft² °F

C_p = panas jenis = 0,9117 BTU/lb.F

μ = viskositas cairan = 0,46174 lb/ft jam

μ_w = viskositas pendingin = 1,16358 lb/ft jam

$$h_o = 4600 \times \frac{1,6955}{4,175} \left(\frac{0,9117 \times 1,1635}{1,6955} \right)^{1/3} \times \left(\frac{0,4617}{1,1635} \right)^{0,14}$$

$$h_o = 912,3322 \frac{BTU}{jam. ft. F}$$

Clean Overall Heat Transfer (U_c)

$$U_c = \frac{h_{io} \cdot h_o}{h_{io} + h_o}$$

$$= \frac{2675 \times 912,3322}{2675 + 912,3322} = 680,352 \frac{BTU}{jam ft^2 F}$$

Design Overall Heat Transfer Corrected (Ud)

Dari Kreith Tabel 12.2 diambil nilai $R_d = 0,0001 \text{ jam.ft}^2.F / \text{BTU}$

$$hd = \frac{1}{R_d} = \frac{1}{0,0001} = 10000 \frac{\text{BTU}}{\text{jam.ft}^2.F}$$

$$Ud = \frac{Uc \times hd}{Uc + hd} = \frac{680,352 \times 10000}{680,352 + 10000} = 637,0135 \frac{\text{BTU}}{\text{jam ft}^2 F}$$

Luas Transfer Panas (A_0)

$$A_0 = \frac{Q}{Ud \cdot \Delta T_{LMTD}} = \frac{6589594 \frac{\text{BTU}}{\text{jam}}}{637,0135 \frac{\text{BTU}}{\text{jam ft}^2 F} \times 34,7459 F} = 297,7185 \text{ ft}^2$$

Luas Perpindahan Panas Per Coil (A')

$$A' = A_0 \cdot \pi \cdot D_{\text{coil}}$$

$$A' = 1,734 \frac{\text{ft}^2}{\text{ft}} \cdot \pi \cdot 4,175 \text{ ft} = 22,7525 \text{ ft}^2$$

Jumlah Lilitan Coil (N_t)

$$N_t = \frac{A_0}{A'} = \frac{297,7185 \text{ ft}^2}{22,7525 \text{ ft}^2} = 13,085 \text{ -----} \rightarrow 13 \text{ lilitan}$$

Jarak Antara Coil (P_t)

$$P_t = 0,5 \text{ in} = 0,04166 \text{ ft} = 0,0127 \text{ m}$$

Area Coil ($A_{OD\ coil}$)

$$A_{OD\ coil} = (\pi/4) \cdot OD^2 = (\pi/4) \cdot (6,625\ in)^2 = 34,485\ in^2 = 0,0222\ m^2$$

Panjang Coil Per Turn ($L_{coil\ per\ turn}$)

$$L_{coil\ per\ turn} = \pi \times D_{coil} = \pi \times 1,27254\ m = 3,999\ m$$

Tinggi Coil Minimum ($H_{c\ min}$)

Tinggi lilitan coil minimum yaitu jika coil disusun tanpa jarak :

$$H_{c\ min} = Nt \times OD_{coil} = 13 \times 6,625\ in = 86,125\ in = 7,177\ ft = 2,187\ m$$

Tinggi Coil Total (H_{coil})

$$\begin{aligned} H_{coil} &= H_{c\ min} + ((Nt-1) \times Pt) \\ &= 86,125\ in + ((13-1) \times 0,5\ in) \\ &= 92,125\ in = 7,677\ ft = 2,339\ m \end{aligned}$$

Voulume Coil (V_{coil})

$$V_{coil} = A_{OD\ coil} \times L_{coil\ per\ turn} \times Nt$$

$$V_{coil} = 0,0222\ m^2 \times 3,999\ m \times 13 = 1,156\ m^3$$

Dari perhitungan dimensi coil, dapat diketahui coil tercelum atau tidak.

Tinggi coil dalam reaktor = 2,339 m

Tinggi reaktor = 3,5029 m

$$\begin{aligned} H_{\text{cairan}} &= \frac{(V_{\text{cairan}} + V_{\text{coil}} + V_{\text{baffle}} + V_{\text{pengaduk}} - V_{\text{head}})}{A_{ID \text{ reaktor}}} \\ &= \frac{(8,345 \text{ m}^3 + 1,156 \text{ m}^3 + 0,0109 \text{ m}^3 + 0,0255 \text{ m}^3 - 0,9867 \text{ m}^3)}{3,534 \text{ m}^3} \\ &= 2,419 \text{ m}^3 \end{aligned}$$

Tinggi cairan didalam reaktor > tinggi coil didalam reaktor. Dapat disimpulkan semua coil tercelup didalam reaktor.

KESIMPULAN REAKTOR

Tugas mereaksikan aseton sebanyak 3134 kg/jam dan kalsium hipoklorit sebanyak 7015 kg/jam menjadi kloroform.

Jenis Alat Reaktor Alir Tangki Berpengaduk.

Kondisi Operasi Isotermal pada suhu 61 °C dan tekanan 2 atm waktu tinggal 5 menit.

Volume reaktor = 12,4049 m³

Diameter = 2,1336 m

Tinggi = 3,5 m

Volume cairan dalam head = 0,986 m³

Volume cairan dibadan reaktor = 10,431 m³

Tinggi cairan dibadan reaktor = 7,358 m³

Tebal shell = 5/16 in

Tebal head = 5/16 in

Jenis pengaduk : Flat Blade Turbine, 4 baffle, 6 blade

Diameter impeller = 0,7059 m

Tinggi blade = 0,141 m

Lebar baffle = 0,1764 m

Daya motor = 5 Hp

Dimensi lubang :

- Inlet arus 1
 - *Nominal pipe size* (Nps) = 1,25 in
 - *Schedule Number* (Sch) = 40
 - *Outside Diameter* (OD) = 1,66 in
 - *Inside diameter* (ID) = 1,38 in
- Inlet arus 5
 - *Nominal Pipe Size* (Nps) = 6 in
 - *Schedule Number* (Sch) = 40
 - *Outside Diameter* (OD) = 6,625 in
 - *Inside Diameter* (ID) = 6,065 in
- Outlet arus 5
 - *Nominal Pipe Size* (Nps) = 6 in

- *Schedule Number* (Sch) = 40
- *Outside Diameter* (OD) = 6,625 in
- *Inside Diameter* (ID) = 6,065 in

Luas perpindahan panas :

A = 297,7185 ft^2

Tipe coil = Helical Coil

Media pendingin = Air

Diameter coil per helic = 1,2725 m

Jumlah lilitan coil = 13 lilitan

Jarak antar coil = 0,5 in

Total coil total = 2,339 m