C. Merancang Koil Pemanas

Reaktor beroperasi secara isotermal. Karena reaksi endotermis, panas yang dibutuhkan reaksi harus ditransfer (diserap) ke reaktor untuk mencegah penurunan temperatur. Koil pemanas digunakan untuk menjaga temperatur reaktor pada 275 ^oC.

Pertimbangan penggunaan koil :

- Koil bisa langsung bersinggungan dengan fluida, sehingga trasfer panas bisa efektif
- Luas transfer panas koil bisa diatur
- Panas tercampur lebih homogen didalam fluida
- Paling murah (Kern, 1950, pp. 720)

Digunakan *Steam* sebagai pemanas pada reaktor :

Kebutuhan Pemanas :

Massa *steam* = 14.895 kg/jam = 32.838 lb/jam

Sifat steam pada suhu rata-rata = 325 ^oC		
ρ =	11,11	lb/ft^3
μ =	0,002 cP	= 0,005 lb/ft.jam
Cp =	2.412,2	Btu/lb^oF
k =	1,1	$Btu/jam.ft.^oF$

Trial pemilihan pipa standar (Tabel. 13, Timmerhaus, 1991) :

Dipilih *tube* :

NPS = 1 in

OD = 1,32 in = 0,11 ft

ID = 1,049 in = 0,087417 ft

a_t'' = 0,344 ft^2/ft

a' = 0,864 in^2/tube = 0,006 ft^2/tube

Hot Fluid	**^oF**	***Cold fluid***	***Temp. diff***	**^oF**
662	*Higher Temp*	527	135	**Δt_2**
572	*Lower Temp*	527	45	**Δt_1**
90	*Temp diff*	0	90	**$\Delta(t_2 - t_1)$**

Sehingga :

$$\Delta T_{LMTD} = \frac{\Delta(t_2 - t_1)}{Ln\left(\Delta t_2 / \Delta t_1\right)}$$

$$= 81,92\ ^oF$$

- Fluks Massa Pemanas Total (G_{tot})

$$G_{tot} = \frac{w}{a'_t}$$

$$= \frac{32.838\ \frac{lb}{jam}}{0,006\ ft^2} = 486797,3167\ lb_m/ft^2.jam$$

- Fluks Massa Tiap Set Koil

$G_i = \rho_c \times v_c$

Kecepatan medium pemanas di dalam pipa umumnya berkisar 1,5-2,5 m/s.

Dipilih : V_c = 2,5 m/s = 8,20 ft/s.

$G_i = \rho_c \times v_c$

G_i = 12,9386 x 8,2021 = 106,1237 lb/s.ft^2

= 382.045,2878 lb/jam.ft^2

- Jumlah Set Koil (N_c)

$$N_c = \frac{G_{c,tot}}{G_i}$$

$$N_c = \frac{486797{,}316\ 7}{382.045{,}28\ 78} = 1{,}2742\ set\,koil = 2 set\,koil$$

- Koreksi Fluks Massa Tiap Set Koil ($G_{i,kor}$)

$$G_{i,kor} = \frac{G_{c,tot}}{N_c}$$

$$G_{i,kor} = \frac{486797{,}316\ 7}{2} = 243398{,}6584\ \ lb\,/\ jam.ft^2$$

- Cek Kecepatan Medium Pemanas ($V_{c,cek}$)

$$V_{c,cek} = \frac{G_i}{\rho_c}$$

$$V_{c,cek} = \frac{243398{,}658\ 4}{12{,}94} = 18809{,}7881\ ft\,/\ jam = 1{,}5926\ m\,/\,s$$

(masuk dalam range/memenuhi standar 1,5 − 2,5 m/s)

- Beban Panas Tiap Set Koil (Q_{ci})

Asumsi : beban panas terbagi merata pada tiap set koil

Q_c = 1814504,5680 kj/jam

$= 1719818{,}4944$ Btu/jam

$$Q_{ci} = \frac{Q_c}{N_c}$$

$$Q_{ci} = \frac{1719818{,}4944}{2} = 859909{,}2472\ Btu/jam$$

- Luas Perpindahan Panas Tiap Set Koil

$$A_{ci} = \frac{Q_{ci}}{U_D \times \Delta T_{LMTD}}$$

$$A_{ci} = \frac{859909{,}2472}{(75)(269{,}1166)}$$

$$= 43{,}7216\ ft^2$$

- Jarak Antar Pusat Koil (J_{sp})

$J_{sp} = 2 \times OD_{koil}$

$J_{sp} = 2 \times 0{,}11$

$= 0{,}22$ ft

- Panjang Satu Putaran Heliks Koil (L_{he})

L_{he} = ½ putaran miring + ½ putaran datar

$$L_{he} = 1/2.\pi.r_{he} + 1/2.\pi.d_{he}$$

Diameter *spiral* atau heliks koil = 0,7-0,8 Dv (Rase, 1977)

D_{spiral} (d_{he}) = 0,8 (5,9357 ft)

= 2,0337 m

= 6,6724 ft

$$L_{he} = 1/2\pi(d_{he}^2 + J_{sp}{}^2)^{1/2} + 1/2\pi.d_{he}$$

$$L_{he} = 1/2\pi(6{,}6724^2 + 0{,}22^2)^{1/2} + 1/2\pi\, x 6{,}6724$$
$$= 20{,}9570\ ft$$

- Panjang Koil Tiap Set (L_{ci})

$$L_{ci} = \frac{A_{ci}}{a_t^{"}}$$

$$L_{ci} = \frac{43{,}7216}{0{,}344}$$
$$= 127{,}0977\ ft$$

- Jumlah Putaran Tiap Set Koil

$$N_{pc} = \frac{L_{ci}}{L_{he}}$$

$$N_{pc} = \frac{127{,}0977\ ft}{20{,}9570\ ft}$$
$$= 6{,}0647\ putaran = 6\, putaran$$

- Koreksi Panjang Koil Tiap Set

$L_{ci,kor} = N_{pc}$ x L_{he}

$L_{ci,kor}$ = 6 x 20,9570

= 125,7422 ft

- Tinggi Koil (L_c)

L_c = Jsp x Npc x Nc

L_c = 0,22 x 6 x 2

= 2,64 ft

= 0,8047 m

- Volume Koil (V_c)

$V_c = N_c\ (\pi/4\,(OD)^2\ L_{ci})$

$V_c = 2\ (\pi/4 \times 0{,}11^2 \times 125{,}7422 = 2{,}3887\ ft^3 = 0{,}0676\ m^3$

Cek tinggi cairan setelah ditambah koil (H_L)

Tinggi koil harus lebih kecil dari pada tinggi cairan setelah ditambah koil agar seluruh koil tercelup dalam cairan

$$H_L = \frac{V_{cair} + V_{koil}}{\left(\pi/4\,D_{vessel}^{\ 2}\right)}$$

$$= \frac{38{,}7138 + 0{,}0676}{3{,}14/4\,(2{,}5422^2)}$$

= 7,6460 m

H_L = 7,6460 m > Hc = 0,8047 m, berarti semua koil tercelup semua di dalam cairan

- Koefisien transfer panas fluida sisi dalam *tube*:

$$h_i = J_H\left(\frac{k}{ID}\right)\left(\frac{C_p\,\mu}{k}\right)^{1/3} \qquad \text{(Pers. 6.15, Kern)}$$

$$N_{Re} = \frac{ID.G_t}{\mu}$$

$$= \frac{(0{,}087417)(486797{,}3167)}{0{,}63151} = 67385{,}0945$$

J_H = 170

$$h_i = 170\left(\frac{0{,}35432413}{0{,}087}\right)\left(\frac{(0{,}0011)(0{,}631)}{0{,}35432413}\right)^{1/3}$$

= 86,6538 Btu/ jam.ft^2 ^{o}F

Maka h_{io} koil = h_{io} pipa (1 + 3,5 $\left(\dfrac{D\,koil}{D\,spiral}\right)$

= 86,6538 (1 + 3,5 $\left(\dfrac{0{,}087417}{5{,}2990}\right)$

= 91,6571 Btu/hr ft ^{o}F

koefisien transfer fluida sisi luar koil :

ΔT = 302 – (-28,3) = 330,3 °F

t_f = (302 + (-28,3))/2 = 136,85 °F

$\dfrac{\Delta T}{OD}$ = 330,3/1,32 = 250,2273

h_o = 116 $\left(\left(\dfrac{kf^3\,x\,\rho^2\,x\,C_f\,x\,\beta}{\mu_f}\right)\left(\dfrac{\Delta T}{OD}\right)\right)^{0,25}$ (pers 10.14 Kern 1950)

Dari Fig 10.4 Kern diperoleh $\dfrac{k^3\,x\,\rho^2\,x\,C\,x\,\beta}{\mu}$ = 0,014

Maka h_o = 116 (0,014 x 250,2273)^{0,25}

= 158,6988 Btu/hr ft ^{o}F

Menghitung *clean overall coefficients* (Uc)

Uc = $\dfrac{h_o\,x\,h_{io}}{h_o + h_{io}}$

= $\dfrac{158{,}6988\;x\,91{,}6571}{158{,}6988\;+91{,}6571}$

= 58,1008 Btu/jam ft^2 ^{o}F

Diambil Rd = 0,001 (Tabel 12 Kern, 1950)

$$U_D = \frac{1}{\left(\frac{1}{U_c} + Rd\right)}$$

$$= \frac{1}{\left(\frac{1}{58{,}1008} + 0{,}001\right)}$$

$$= 54{,}9105$$

Batasan U_D untuk light – light organik adalah 40-75 maka nilai U_D yang didapat dari hasil hitungan adalah 54,9105 memenuhi batas.

- Cek *Dirt Factor*

Dari tabel 12 Kern, 1965, R_d ketentuan untuk *Steam* = 0,002

Syarat : $R_d < R_d$ ketentuan

$$R_d = \frac{U_c - U_D}{U_c x U_D}$$

$$R_d = \frac{58{,}1008 - 54{,}9105}{58{,}1008 x 54{,}9105} = 0{,}0011 > 0{,}002\ (memenuhi)$$

- Cek *Pressure Drop*

Syarat : < 2 psi

$$R_{ei} = \frac{ID \times G_i}{\mu_c}$$

$$R_{ei} = \frac{0{,}087417\ x\ 243398{,}6583}{0{,}6315} = 33693{,}0808$$

Faktor friksi :

$$f = 0{,}0035 + \frac{0{,}264}{R_{ei}^{\;0,42}}$$

$$f = 0{,}0035 + \frac{0{,}264}{33693{,}0808^{\,0,42}} = 6{,}8116 \times 10^{-5}$$

- *Pressure Drop*

$$\Delta P = \frac{4.f.G_i^2.L_i}{2g.\rho_c^{\;2}.ID}$$

$$\Delta P = \frac{4(6{,}8116.10^{-5})(243398{,}6583^2)133{,}1672}{2(4{,}18x10^8)(12{,}94^2)(0{,}087417)} = 0{,}6705\ psi$$