LAMPIRAN A

DESAIN EVAPORATOR (EV-01)

Fungsi : Menguapkan kandungan air didalam susu kedelai

Jenis : Horizontal Tube Evaporator

Bahan : *Stainless steel,* SA-316 *grade C*

Jumlah : 1 unit

Laju umpan masuk (F) : 4820,5859 kg/jam

Densitas susu kedelai (ρ) : 1000,765 kg/m^3 = 62,475 lbm/ft^3 (LC.22)

Volume total umpan masuk = $\frac{F}{\rho} = \frac{4820,5859}{1000,765}$ = 4,816 m^3

Perhitungan :

Ukuran tangki

Faktor kelonggaran = 20%

Volume tangki = 1,2 x 4,816 m^3 = 5,779 m^3

Volume shell tangki (Vs) :

Vs = ¼ $\boldsymbol{\pi}$Dt$^{\mathbf{2}}$Ht

Direncanakan perbandingan diameter dengan silinder tangki : Dt : Ht = 3 : 4

Vs = $\frac{8}{24}$ $\boldsymbol{\pi}$Dt$^{\mathbf{3}}$

Volume tutup tangki (Ve) :

Ve = $\frac{\boldsymbol{\pi}}{24}$ (Brownell, 1959)

Volume tangki (V) :

V = Vs + Ve

V = $\frac{9}{24}$ $\boldsymbol{\pi}$Dt$^{\mathbf{3}}$

5,779 m^3 = $\frac{9}{24}$ $\boldsymbol{\pi}$Dt$^{\mathbf{3}}$

5,779 m^3 = 1,1775Dt^3

$\frac{5,779}{1,1775} = Dt^3$

4,907 = Dt^3

Dt = 1,699 m

Ht = 2,266 m

Tinggi tutup, He = $\frac{Dt}{4} = \frac{1,699}{4}$ = 0,425 m

Tinggi *shell,* Hs = Ht – 2He = 2,266 – 2(0,425) = 1,416 m

Tekanan Design :

Volume tangki = 5,779 m^3

Volume cairan = 4,816 m^3

Tinggi tangki = 2,266 m

Tinggi cairan dalam tangki = $\frac{volume\ cairan\ dalam\ tangki\ x\ tinggi\ tangki}{volume\ tangki}$

Tinggi cairan dalam tangki = $\frac{4,816\ x\ 2,266}{5,779}$ = 1,888 m

Tekanan hidrostatis = ρ x g x tinggi cairan dalam tangki

= 1000,765 x 9,8 x 1,888

= 18.516,55 Pa

= 18,516 kPa

Faktor keamanan = 20%

Tekanan design = 1,2 x 18,516

= 22,219 kPa

Tebal dinding tangki :

Joint effisiensi = 0,8 (Brownell, 1959)

Allowable stress = 12.650 psia = 87.218,7140 kPa (Brownell, 1959)

Tebal *shell* tangki :

$$t = \frac{PD}{2SE-1,2P}$$

$$t = \frac{(22,219)(1,699)}{2(87.218,714)(0,8)-1,2(22,219)}$$

$$t = \frac{37,75}{139549,94-26,663}$$

t = 0,0002705 m = 0,0106 in

Faktor korosi = 0,125 in

Maka tebal dinding tangki yang dibutuhkan = 0,0106 in + 0,125 in = 0,136 in

Tebal tutup = tebal dinding tangki = 0,136 in

Tenaga pengaduk

Jenis pengaduk : *Propeller 3 Blades*

Jumlah *baffle* : 4 buah

Untuk turbin standar (Geankoplis, 1997), diperoleh :

Da/Dt = 1/3 ; Da= 1/3 x 1,699 m = 0,566 m = 1,856 ft

C/Dt = 1/3 ; E = 0,566 m = 1,856 ft

L/Da = ¼ ; L = ¼ x 0,566 = 0,1415 m = 0,464 ft

W/Da = 1/5 ; W = 1/5 x 0,566 = 0,1132 m = 0,371 ft

J/Dt= 1/12 ; J = 1/12 x 1,699 = 0,1415 m = 0,464 ft

Kecepatan pengadukan, N = 0,5 putaran/sec

Da = 0,566 m = 1,856 ft

Bilangan Reynold,

$$N_{Re} = \frac{Da^2 N \rho}{\mu} = \frac{1,856\, ft^2 .\, 0,5\, put/\sec .\, 62,475}{0,00142 5 \frac{lbm}{ft}.sec} = 75.512,24$$

Dari gambar 3.4-4 Geankoplis, untuk N_{Re} = 75.512,24 maka diperoleh

Np = 1

Np = ρ $\frac{P}{N^3\ Da^5}$, maka :

= Np . ρ . N^3 . Da^5 = (1) (1000,765) $(0{,}5)^3$ $(0{,}566)^5$ = 7,255 watt = 0,009 Hp

Effisiensi motor penggerak = 80%

Daya motor penggerak = $\frac{0{,}009}{0{,}8}$ = 0,01125 Hp

Koil Pemanas

Bebas panas (Q) = 12115,694 kJ/jam = 11483,462 Btu/jam

Massa steam (m_s) : 5,73 kg/jam = 12,632 lb/jam

T_{in} = 65°C = 149°F

T_{out} = 102°C = 215,6°F

Jenis koil pemanas yang digunakan adalah *single helix*

Densitas steam = 953,58 kg/m^3 (Geankoplis, 1997)

Laju alir volumetric steam = $\frac{5{,}73\ kg/jam}{(953{,}58\frac{kg}{m^3})(1\ jam)}$ = 6,008e-3 m^3/jam = 1,668e-6 m^3/det

Di,opt = 0,363 x $Q^{0,45}$ x $\rho^{0,13}$

= 0,363 x $(1{,}668e-6)^{0,45}$ x $(953{,}58)^{0,13}$

= 2,224e-3 m

Ukuran spesifikasi pipa : (Geankoplis, 1997)

- Ukuran pipa nominal = 1 in
- *Schedule* pipa = 40
- Diameter dalam (ID) = 1,0490 in = 0,0874 ft
- Diameter luar (OD) = 1,3150 in = 0,1096 ft
- Luas penampang dalam (At) = 0,0060 ft^2

Mass velocity (G) = $\frac{12{,}632\ lbm/jam}{0{,}0060\ ft^2}$ = 2.105,33 lbm/ft^2.jam

Properti uap dikoreksi pada suhu 150°C

Viskositas uap = 0,1935 cp = 0,4681 lbm/ft.jam (Geankoplis, 1997)

- Bilangan Reynold

$N_{Re} = \frac{Di.G}{\mu} = \frac{(0,0874)(2.105,33)}{0,4681} = 393,090$

Dari gambar 24 Kern, 1988 diperoleh $j_H = 900$

Cp uap = 1,0299 btu/lbm.ft.°F

k = 0,3949 btu/h.ft.°F

hi $= j_H \frac{k}{Di} \frac{c\,x\,\mu/13}{k}$ x 1

Koreksi viskositas = $(\frac{\mu}{\mu w})^{0,14} = 1$

hi $= 900 \text{ x } \frac{0,3949}{0,0874} \text{ x } \frac{1,0299\ x\ 0,4681/13}{0,3949}$ x 1

= 4346,107 btu/h.ft.°F

Outside heat transfer coefficient

Hio = hi x $\frac{ID}{OD}$ = 4346,107 x $\frac{0,0874}{0,1096}$ = 3465,782 btu/h.ft^2.°F

Clean overall coefficient

Uc = $\frac{hi+hio}{hi\,.\,hio} = \frac{4346,107+3465,782}{4346,107\ x\ 3465,782}$ = 1928,171

Design overall coefficient

Dirt *Factor* (R_D) = 0,003 ; h_d = 1/0,003 = 333,3

$U_D = \frac{Uc\ x\ hd}{Uc+hd} = \frac{1928,171\ x\ 333,3}{1928,171+333,3}$ = 284,177 btu/h.ft^2.°F

Luas permukaan perpindahan panas

A = $\frac{Q}{UD\ X\ \Delta t} = \frac{11483,462}{284,177\ x\ (215,6-149)}$ = 0,606 ft^2

Panjang linier *tube* koil

L = $\frac{A}{2\pi Di} = \frac{0,606}{2\ x\ 3,14\ x\ 0,0874}$ = 1,105 ft = 0,336 m

Volume total koil

Vc = At x L = 0,0060 ft^2 x 1,105 ft = 6,63e-3 ft^3

Jumlah dan tinggi lilitan

Diameter lilitan (Dc) = 0,6 x Dt = 0,6 x 1,699 = 1,0194 m

Jarak vertikal antar lilitan (n) = 1 in = 0,0254 m

N = $\frac{L-(n\ x\ Ntrial)}{\pi\ x\ Dc}$

N trial = 50 lilitan

N = $\frac{0{,}336\ (0{,}0254\ x\ 50)}{3{,}14\ x\ 1{,}0194}$ = 0,133 lilitan

Dipakai 0,133 lilitan

Panjang *tube* koil baru = (0,133 x 3,14 x 1,0194) + (0,0254 x 0,133) = 0,429 m

Tinggi lilitan (hi) = n(N-1) + N(OD) = (1 x 0,133) + (0,133 x 1,315) = 0,307 in