BAB X
TUGAS KHUSUS

10.1. Pendahuluan

Industri kimia merupakan industri yang mengolah bahan baku menjadi produk dengan memanfaatkan proses-proses kimia. Pada pra rancangan pabrik hidrogen ini menggunakan limbah Ampas Tebu sebagai bahan baku utama dan produk utama yaitu *hydrogen* sedangkan produk samping yang terbentuk yaitu *syngas*. Metode yang digunakan untuk mengkonversi ampas tebu menjadi *hydrogen* yaitu gasifikasi. Proses gasifikasi dari limbah terjadi pada temperature tinggi dengan penambahan steam yang terkontrol. Beberapa produk berupa campuran gas atau yang dikenal dengan istilah *syngas*, reaksi dasar gasifikasi dari limbah ampas tebu.

- Reaksi 1 :
  $C_{3,65}H_{5,8}O_{2,94} + 0,71H_2O \longrightarrow 3,65CO + 3,61H_2$
- Reaksi 2 :
  $C_{3,65}H_{5,8}O_{2,94} + 4,36H_2 \longrightarrow 3,65\ CO_2 + 7,26H_2$
- Reaksi 3 :
  $CO + H_2O \longrightarrow CO_2 + H_2$
- Reaksi 4 :
  $CO + 3H_2 \longrightarrow CH_4 + H_2O$

10.2. Ruang Lingkup Rancangan

Perancangan peralatan proses yang digunakan dalam produksi *hydrogen* dari Ampas tebu terdiri atas:

- Reaktor
- Alat transportasi
- Alat perpindahan panas
- Alat pemisah

Reaktor merupakan tempat terjadinya reaksi kimia dalam proses produksi gas sintesa berupa gas hidrogen. Alat transportasi cacahan umpan berupa *Kompresor*, alat perpindahan panas *Cooler* dan untuk alat pemisah berupa *Cyclone*. Rancangan lengkap peralatan proses dapat dilihat pada sub bab rancangan.

10.3. Rancangan

10.3.1. Reaktor Gasifikasi (GS-2041)

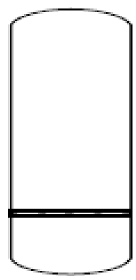
Fungsi : Mengubah Sampah platik menjadi gas sintesa

Tipe : *Fluidized Bed Reactor*

Bahan : *Stainless steel*

Jumlah : 1 unit

Gambar :



Data,

- Massa umpan masuk : 1997,487346 kg/jam
- Tekanan : 8 atm
- Temperatur operasi : 850 ^oC
- Temperatur masuk : 105 ^oC
- Densitas umpan : 111 kg/m^3
- Waktu reaksi : 1 jam
- Diameter umpan : 20 mm

- **Menghitung Viskositas**

Komponen	Tc (K)	Pc (atm)	μ (centipoise)	fraksi mol
H2O	425,15	8	0,003192563	0,19997665
SCB	378,15	1	0,012772116	0,80002335
Total			0,015964678	1

Sumber: transport phenomena

$$T_c = (0{,}8\ x\ T_{c\,SCB}) + \ (0{,}19997\ x\ T_{cH2O})$$

$$T_c = 387{,}5489026\ k$$

$$P_c = (0{,}0127\ \ x\ P_{c\ SCB}) + (0{,}0031\ \ x\ P_{cH2O})$$

$$P_c = 2{,}39\ atm$$

$$\mu_c = \left(0{,}8\ x\ \mu_{c\ SCB}\right) + \left(0{,}19997\ x\ \mu_{cH2O}\right)$$

$$\mu_c = 0{,}010856429\ \frac{gr}{cmdt}$$

$$T_r = \frac{T}{Tc} = \frac{378{,}15\ k}{387{,}5489026\ \ k} = 0{,}975747828\ k$$

$$P_r = \frac{P}{Pc} = \frac{8\ atm}{2{,}39\ atm} = 3{,}333\ atm$$

$$\mu = 0{,}0221866723\ \frac{gr}{cmdt}$$

Dari transport phenomena, fig 1.3.1, untuk harga Tr dan pr diatas didapat harga μ = 0,0221866723

$$\mu = \frac{\mu_g}{\mu_c}$$

$$\mu_g = 0{,}0221866723 \text{ x } 0{,}010856429\ \ \frac{gr}{cmdt} = 0.0002248251\ \frac{gr}{cmdt}$$

1) menghitung diamter partikel rata –rata

$$dp" = \frac{1}{\Sigma(\frac{xi}{dpi})}$$ (wallas hal 147)

$$\Sigma\left(\frac{xi}{dpi}\right) = \frac{m_{umpan}}{m_{partikel\ x\ d_{umpan}}}$$

$$\Sigma\left(\frac{xi}{dpi}\right) = \frac{1997{,}487346kg}{1997{,}487346\ kg\ x\ 20\ mm}$$

$$\Sigma\left(\frac{xi}{dpi}\right)$$ = 0,05 mm

$$dp" = \frac{1}{\Sigma(\frac{xi}{dpi})}$$

$$dp" = \frac{1}{0{,}05\ mm}$$

$$dp" = \ 20\ mm = \ 2\ cm\ = 0{,}002\ m$$

- **Menghitung kecepatan volumetrik umpan (Q)**

$$Q = \frac{m}{\rho}$$

$$Q = \frac{1997{,}487346 g/jam}{111 \text{ kg/m}^3}$$

$$Q = 17{,}9953815 \frac{m^3}{jam}$$

$$Q = 4998{,}717083 \frac{cm^3}{dt}$$

- **Menghitung Volume reaktor**

$$v_r = Q \; x \; \tau$$

$$v_r = 17{,}9953815 \frac{m^3}{jam} x \; 1 \; jam$$

$$v_r = 17{,}9953815 m^3$$

Kapasitas reaktor = Volume reaktor (v_r) = 17,9953815 m^3

Faktor keamanan = 20%

Maka,

Volume reaktor (V_r) menjadi = $\frac{17{,}9953815 \; m^3}{0.8}$

$$v_r = 22{,}49422687 \; m^3$$

- **Menghitung laju minimum fluidisasi (umf)**

$$Re_{mf} = \frac{d_p \; x \; U_{mf} \; x \; \rho}{\mu} = [(27.2)^2 + 0.0408 \; x \; (Ar)]^{\frac{1}{2}} = 27.2$$

$$Ar = \frac{\rho \; x \; (\rho_p - \rho) x \; g \; x \; d_p^3}{\mu^2}$$

$$\frac{d_p \; x \; U_{mf} \; x \; \rho}{\mu} = [(27.2)^2 + \frac{(0.0408) x \; \rho \; x \; (\rho_p - \rho) x \; g \; x \; d_p^3}{\mu^2}]^{\frac{1}{2}} = 27.2$$

$$\frac{0{,}012 \; x \; umf \; x \; 1{,}122}{0{,}0022083} = [(27.2)^2 + \frac{(0{,}0408) x \; 0{,}92 \; x \; (1{,}11 - 0{,}92) x \; 980.66 \; x \; 0.002^3}{2^{\;2}}]^{\frac{1}{2}} = 27.2$$

$$Umf = 9{,}26330304 \; \frac{cm}{detik}$$

U_f = 5 x U_{mf}

U_f = 5 x 9,26330304 $\frac{cm}{detik}$

U_f = 46,3165152 $\frac{cm}{detik}$

- **Menghitung terminal velocity (umb)**

$$U_{mb} = [\frac{3.1\ x\ (\rho_{p-}\rho_{g})\ x\ d_p\ .g}{\rho_g}]^{0.5}$$ (wallas hal 149)

$$U_{mb} = [\frac{3,1\ x\ (1,11 - 0,92)\ x\ 2\ .980}{0,92}]^{0.5}$$

$$U_{mb} = [\frac{125,48260827}{0,92}]^{0.5} \frac{cm}{s}$$

$$U_{mb} = 139,4251208^{.5}$$

$$U_{mb} = 11,67879017\ \frac{cm}{s}$$

- **Menghitung voidage minimum**

$$\varepsilon^3_{mb}/(1-\varepsilon_{mb}) = 47.4(gd_p^3\rho_p^2/\mu^2)^{-0.5}.$$

$$\frac{\varepsilon^3 mb}{(1-\varepsilon mb)} = 47.4\ x\ (\frac{g\ x\ dp^3 x\rho_p{}^2}{\mu^2})^{-0.5}$$

$$\frac{\varepsilon^3 mb}{(1-\varepsilon mb)} = 47.4\ x\ (\frac{\mu^2}{g\ x\ dp^3 x\rho_p{}^2})^{0.5}$$

$$\frac{\varepsilon^3 mb}{(1-\varepsilon mb)} = 47.4\ x\ (\frac{0,0221866723\ ^2}{980.66\ x\ 2^3 x 0,0221866723^2})^{0.5}$$

$$\frac{\varepsilon^3 mb}{(1-\varepsilon mb)} = 0,000249117$$

$$\frac{\varepsilon^3 mb}{(1-\varepsilon mb)} = 0,015783$$

$$\varepsilon^3 mb = 0,015783 - 0,74\ \varepsilon mb$$

$$\varepsilon mb = 0,555672$$

- **Menghitung diameter zona reaksi (D_t)**

U_{mf} = 9,26330304 cm/dt

U_{mb} = 11,67879017 $\frac{cm}{s}$

$$\frac{U_{mb}}{U_{mf}} = 1,26075873\ \frac{cm}{s}$$

V_0= 5.84 x U_{mf}

V_0= 5.84 x 1,26075873cm/dt = 11,6787 cm/dt

$$A = \frac{Q}{V_0}$$

$$A = \frac{4998{,}717083 cm^3/dt}{11{,}6787\ \mathrm{cm/dt}} = 428{,}0166875\ cm^2$$

$$D_t = [\frac{4 \times A}{V_0}]^{0.5}$$

$$D_t = [\frac{428{,}0166875 \times 4}{11{,}6787}]^{0.5}$$

$$D_t = [\frac{1712{,}06675}{11{,}6787}]^{0.5}$$

$$D_t = 41{,}18344275\ cm = 0{,}4118\ m$$

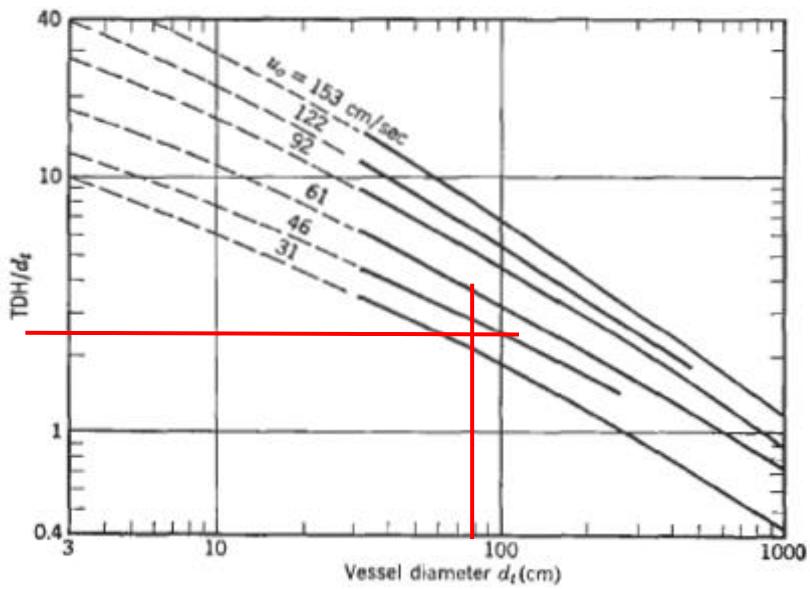
$$D_t = 0{,}4118\ m$$

- **Menghitung transport disengaging height (TDH)**

  V_0 =11,6787cm/dt

  D_t = 0,5 cm

  Dari wallas fig 6.10 didapatkan TDH/D_t = 1,3



(i)

Figure 6.10

TDH = 2,5 x D_t

TDH = 1,02986 m

- **Menghitung tinggi elipsoidal (He)**

  Dipilih heat elipsoidal, sehingga

  He = 0,25 x D_t

  He = 0,102958606 m

- **Menghitung tebal dinding reaktor**

  Data operasi;

  - Tekanan : 117,6 psi = 8 atm
  - Temperatur : 850^0C = 1123,15 K
  - Diameter reaktor,D : 0,411834426 m = 16,2139 in
  - Jari-jari reaktor, R : 0,205917 m = 8,10696067 in
  - Allowable stress, S : 1700 psi
  - Effisiensi pengelasan,E : 0.85
  - Faktor korosi : 0.05 in/thn

  Faktor korosi untuk 10 tahun penggunaan

TABLE 18.3. Formulas for Design of Vessels under Internal Pressure*

Item	Thickness t(in.)	Pressure P(psi)	Stress S(psi)	Notes
Cylindrical shell	$\boxed{\frac{PR}{SE-0.6P}}$	$\frac{SEt}{R+0.6t}$	$\frac{P(R+0.6t)}{t}$	$t \le 0.25D$, $P \le 0.385SE$
Flat flanged head (a)	$D\sqrt{0.3P/S}$	$t^2S/0.3D^2$	$0.3D^2P/t^2$	
Torispherical head (b)	$\frac{0.885PL}{SE-0.1P}$	$\frac{SEt}{0.885L+0.1t}$	$\frac{P(0.885L+0.1t)}{t}$	$r/L = 0.06$, $L \le D+2t$
Torispherical head (b)	$\frac{PLM}{2SE-0.2P}$	$\frac{2SEt}{LM+0.2t}$	$\frac{P(LM+0.2t)}{2t}$	$M = \frac{3+(L/r)^{1/2}}{4}$
Ellipsoidal head (c)	$\boxed{\frac{PD}{2SE-0.2P}}$	$\frac{2SEt}{D+0.2t}$	$\frac{P(D+0.2t)}{2t}$	$h/D = 4$
Ellipsoidal head (c)	$\frac{PDK}{2SE-0.2P}$	$\frac{2SEt}{DK+0.2t}$	$\frac{P(DK+0.2t)}{2Et}$	$K = [2+(D/2h)^2]/6$, $2 \le D/h \le 6$
Hemispherical head (d) or shell	$\frac{PR}{2SE-0.2P}$	$\frac{2SEt}{R+0.2t}$	$\frac{P(R+0.2t)}{2t}$	$t \le 0.178D$, $P \le 0.685SE$
Toriconical head (e)	$\frac{PD}{2(SE-0.6P)\cos\alpha}$	$\frac{2SEt\cos\alpha}{D+1.2t\cos\alpha}$	$\frac{P(D+1.2t\cos\alpha)}{2t\cos\alpha}$	$\alpha \le 30°$

Tebal dinding silinder, t_s

$$t_s = \frac{PR}{SE-0,6P} + C \qquad \text{(Walas, Tabel 18.3)}$$

$$t_s = \frac{117,6\ \text{psi x } 8,10696067\ \ \text{in}}{(1700\ \text{psi x } 0.85)-(0.6\ x\ 117,6\ \ psi)} + (0.05 \text{ x } 10)$$

t_s = 1,1936 in

t_s = 0,3030 m

t_s = 3,0318 mm

Tebal dinding silinder, t_e

$$t_e = \frac{PD}{2SE-0,2P} + C$$

$$t_e = \frac{117,6psi\ x\ 16,21}{2(1700\ \text{psi x } 0.85)-(0.2\ x\ 117,6\ \ psi)} + (0.05x10)$$

t_e = 1,16519 in

t_e = 0,029595 m

t_e = 2,9595 mm

(b) High Alloy Steels

A.S.M.E. Specification No.	Grade	Nominal composition	Specified minimum tensile strength	For temperatures not exceeding °F. −20 to 100	200	400	700	900	1000	1100	1200	1300	1400	1500
SA-240	304	18 Cr-8 Ni	75,000	18,700	15,600	12,900	11,000	10,100	9,700	8,800	6,000	3,700	2,300	1,400
SA-240	304L†	18 Cr-8 Ni	70,000	15,600	13,300	10,000	9,300							
SA-240	310S	25 Cr-20 Ni	75,000	18,700	16,900	14,900	12,700	11,600	9,800	5,000	2,500	700	300	200
SA-240	316	16 Cr-12 Ni-2 Mo	75,000	18,700	16,100	13,300	11,300	10,800	10,600	10,300	7,400	4,100	2,200	$\boxed{1,700}$
SA-240	410	13 Cr	65,000	16,200	15,400	14,400	13,100	10,400	6,400	2,900	1,000			

- Merancang Pemanas Reaktor

  Diketahui

  T umpan (T0) : 220 °C

  T udara panas (Tc) : 500 °C

  Densitas ρ : 998 kg/m^3

  Panas , Q : 32759,149 kj/jam

Massa udara panas, m : 37917,32458 kg/jam

OD reaktor : 16,21392134 in

Tinggi silinder Hs : 0,617751639 m = 24,32088201 in

koefisien panas, UD : 87,5 btu/jam ft^2.F (kren tabel 8)

1) Menghitung luas perpindahan panas

- Luas perpindahan panas yang tersedia

  A = Luas selimut reaktor + Luas penampang bawah reaktor

  $A = OD.Hs + (\pi/4.OD2)$

  A = 600,7064953 ft^2

  - Luas Area Perpindahan panas (A)

  $A = \frac{Q}{UD\Delta T}$

  A = 1,260133198 ft^2

Akebutuhan < Atersedia (1,260133 ft2 < 4,17157 ft2)

Sehingga jaket pemanas bisa digunakan.

Tinggi jaket (Hj)

asumsi jarak jaket 5 in

Hj = Hs + jarak jaket

= 29,32088201 in

= 0,74475 m

Diameter Luar Jaket, D2

Dj = OD + 2 jarak jaket

= 26,21392134 in

= 0,66583 m

Tekanan Hidrostatik pada jaket (PH)

PH = ρ . g . Hs

= 604,1858126 kg/m^2s

= 0,00586 atm

= 0,8458 psi

Tekanan Desain (Pj)

Pj = P op + PH

= 8,00586 atm

= 117,686159 psi

Tebal dinding jaket (tj)

Jari-jari, R	13,1069	In	
Effisiensi pengelasan, E	0,85		
Allowable stress, S	13700	Psi	peter, Tabel 4 hal 538
Faktor korosi	0,02	in/tahun	Wallas,Tabel 18.4
tahun digunakan	10	Tahun	

$t_j = \frac{PR}{SE - 0{,}6P} + C$ (Walas, Tabel 18.3)

$t_j = \frac{117{,}6\ psi\ x\ 13{,}1069}{(13700\ \text{psi x } 0.85) - (0.2\ x\ 117{,}6\ psi)} + (0.002)$

tj = 0,153170 in

ti = 0,00389 m

10.3.2 Kompresor (BC-1201)

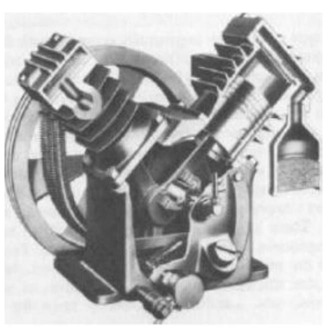
Fungsi : Menaikkan tekanan gas sebelum masuk ke PSA

Bentuk : *Centrifugal compressor*

Bahan : *Carbon Steel*

Jumlah : 1 unit

Gambar :



Data,

- Laju alir massa gas masuk : 2251,933697 kg/jam = 4964,658067 Ib/jam
- Densitas gas : 1,196 kg/m^3
- Temperatur masuk : 30 ℃
- Tekanan masuk, P1 : 1 atm = 14,6959 psi = 101,2970 kpa
- Tekanan keluar, P2 : 24,6 atm = 361,5216 psi = 2492,6036 kpa
- Berat molekul gas : 26,29040652
- Berat molekul rata- udara : 30

Laju alir volumetrik,

$$Q = \frac{m}{\rho}$$

$$Q = \frac{2251{,}933697\ kg/jam}{1{,}196\ kg/m^3}$$

$Q = 1882{,}59 m^3$/jam

$$Q = 1882{,}59\ \frac{m^3}{jam} x \frac{1\ jam}{3600\ detik}$$

$$Q = 0{,}52294167\ \frac{m^3}{detik}$$

Spesifik grafity,

$$S_p = \frac{BM\ gas\ hidrogen}{BM\ rata - rata\ udara}$$

$S_p = \frac{26{,}2904}{30} = 0{,}8763$

Menghitung daya *compressor*

$kW_{ad} = 2{,}78\ x\ 10^{-4}\ \frac{k}{k-1} Q_1 p_1 [\left(\frac{p2}{p1}\right)]^{\frac{(k-1)}{k}} - 1$ (Perry’s 10-66a)

$k = 1{,}3 - 0{,}31\ x\ (\gamma - 0{,}55)$ (Perry’s)

$k = 1{,}3 - 0{,}31\ x\ (0{,}8753 - 0{,}55)$

$k = 1{,}198$

$kW_{ad} = 2{,}78\ x\ 10^{-4}\ \frac{1{,}198}{1{,}198-1}\ 18{,}476\ x\ 2116{,}2204[\left(\frac{52059{,}02189}{2116{,}2204}\right)]^{\frac{(1{,}198-1)}{1{,}298}} - 1$

$kW_{ad} = 45{,}9173$ KW

= 61,2231 HP

Efisiensi compressor 75% = 61,2231 HP / 0,75

= 81,6308 HP

***10.3.3 Cyclone* (CY-3061)**

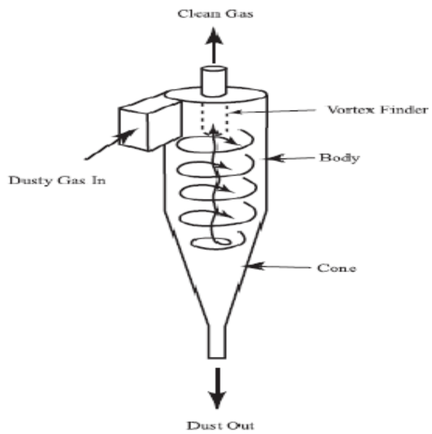
Fungsi : Memisahkan partikel padat dari aliran gas dari gasifer

Tipe : *Centrifugal cyclone*

Bahan : *Carbon Steel*

Jumlah : 1 unit

Gambar :



Data :

- Laju alir umpan total, m : 2306,74475 kg/jam
- Laju alir massa gas masuk : 2251,933697 kg/jam
- Densitas gas : 3.7433926 kg/m^3
- Diameter partikel C : 200 μm
- Kecepatan aliran : 15 m/s (Coulson & Richardson hal 453)
- Tekanan : 8 atm

Volume gas masuk, V(gas)

$$V(gas) = \frac{m\ gas}{\rho\ gas}$$

$$= \frac{2251{,}933697\ kg/jam}{3{,}7433926\ \ kg/m^3}$$

$$= 616{,}2177\ \ m^3/jam$$

$$= 0{,}1713\ m^3/s$$

Area of inlet $= \frac{V\ gas}{kecepatan\ aliran}$

$$= \frac{0{,}1713\ \ m^3/s}{15\ m/s} = 0{,}011421\ m^2$$

$0{,}011421\ m^2 = \ 0{,}1Dc^2$

$$Dc^2 = \frac{0{,}011421\ m^2}{0{,}1}$$

$$Dc = \sqrt{\frac{0{,}011421^{\ 2}}{0{,}1}}$$

$$Dc = 0{,}337943\ m = 13{,}3048\ in$$

Maka, desain *cyclone*

- **Diameter *inlet*** = 0,5 Dc x 0,2Dc
  = (0,5 x 0,337943 m) x (0,2 x 0,337943 m)
  = 0,011420568 m
- **Panjang pipa *vortex*** = 0,5 Dc
  = 0,5 x 0,337943 m
  = 0,168971654 m
- **Tinggi silinder *cyclone*** = 1,5 Dc
  = 1,5 x 0,337943 m
  = 0,506914961 m
- **Tinggi *conical cyclone*** = 2 Dc
  = 2 x 0,337943 m
  = 0,675886615 m
- **Diameter gas *outlet*** = 0,5 Dc
  = 0,5 x 0,337943 m

= 0,168971654 m

- **Diameter *solid outlet*** = 0,375 Dc

  = 0,375 x 0,5551459 m

  = 0,12672874 m

- **Tebal dinding cyclone, t_d**

$$t_d = \frac{PR}{SE - 0{,}6P} + C$$

- Tekanan desain, P : 117,6 psi
- Jari- jari tangki, R : 6,652414 in
- *Allowable stress*, S : 13700 psi (Wallas, Tabel 18,5)
- Efisiensi pengelasan, E : 0,85 (Peter, Tabel 4 hal 538)
- Faktor korosi yang diizinkan : 0,05 in/tahun (Perry's Tabel 23.2)

Maka,

$$t_d = \frac{117{,}6\,psi\ x\ 6{,}652414\,in}{(13700\,psi\ \ x\ 0{,}85) - (0{,}6\ x\ 117{,}6)} + \ 0{,}05$$

= 0.117590647 in = 0,07586 mm

10.3.4 Cyclone (CY-3101)

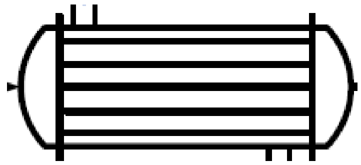
Fungsi : Menurunkan temperatur gas

Bahan : *Carbon Steel*

Tipe : Fire Tube boiler

Jumlah : 1 unit

Gambar :



Data Fluida Panas

- Laju alir massa gas masuk : 2251,933697 kg/jam = 4964,658067 Ib/jam
- Densitas gas : 1,196 kg/m^3
- Temperatur masuk T1 : 850 ℃ = 1562 F
- Temperatur masuk T2 : 30 ℃ = 86 F

Data Fluida dingin

- Laju alir massa gas masuk : 31388,90456 kg/jam = 69200,60677 Ib/jam
- Densitas gas : 1,196 kg/m^3
- Temperatur masuk t1 : 25 ℃ = 77 F
- Temperatur masuk t2 : 55 ℃ = 131 F

Beban Panas : 3284456,501 Kj/jam

$$\boxed{LMTD = (\Delta T2 - \Delta T1) / \ln(\frac{\Delta T2}{\Delta T1})}$$

LMTD = 280,5340 F

Menentukan Temperatur Rata2 (Tav & tav)

T_{av}

$$Tav = \frac{T1 + T2}{2}$$

$$Tav = \frac{1562 + 86}{2}$$

$$Tav = 824\ F$$

t_{av}

$$tav = \frac{t1+t2}{2}$$

$$tav = \frac{131+77}{2}$$

$$tav = 104\ F$$

Menentukan nilai A

Ud = 50 btu/jam ft².°F **(dari tabel 8 D.Q kern utk nilai Ud)**

Q = 3284456.501 kj/jam

$$A = \frac{Q}{Ud\ x\ \Delta TLMTD}$$

$$A = \frac{3284456,501}{50\ x\ 277,7286656}$$

$A = 236{,}5226862\ ft2$

Karena harga A > 200 ft[2], maka tipe Heat Exchanger yang di gunakan adalah *shell and tube exchanger. Dari tabel 10 D. Kern dieroleh asumsi awal rancangan HE.*

Jumlah Tube

$$Nt = \frac{A}{L\ x\ a"}$$

$$Nt = \frac{236{,}5226862}{20\ x\ 0{,}3925}$$

$$Nt = 30{,}1302785$$

$$\text{Ud}= \frac{Q}{Ax\ \Delta T}$$

$$\text{Ud}= 50\frac{btu}{jam} ft2.F$$

Dari tabel 9 (DQ Kern, halaman 841), untuk jumlah tube 30 di dapatkan spesifikasi perancangan heat exchanger sebagai berikut:

Shell

- ID (in) = 19,25
- Baflle Space, B (in) = 3,85
- Passes = 1
- Clearance

Tube

- Jumlah = 50
- Panjang = 20
- OD = 1,5
- BWG = 16
- Pitch = 1 7/8
- Pass = 2

Perhitungan shell and tube

Sheell

$$as = \frac{ID\ x\ C\ "\ x\ B}{144\ x\ PT}$$

tube

$$at = \frac{Nt\ x\ a't}{144\ x\ \mu} \qquad (a't = 1{,}47\ tabel\ 10\ )$$

$as = 1/9ft2$ $at = 0{,}68906$

Laju Alir massa

$Gs = \frac{W}{as}$ $Gt = W/at$

$Gs = 48231\ 1/2$ Ib/ft.jam $Gt = 7204{,}95$ Ib/ft.jam

de= 1,08 (gambar 28)

De= 0,09

Pada t_{av} = 104 F

μ = 0,4 Cp = 1,672 Ib/ft.jam

c = 1 btu/Ib/F

k = 0,36 btu/Ib.ft2

pada T_{av} = 824 F

μ campuran = 0,15 Ib/ft.jam

c Campuran = 0,066 btu/Ib.F

kcampuran = 0,033 btu/jam.ft

$$Res = \frac{De\ x\ Gs}{\mu}$$

$$Res = \frac{4340{,}831071}{1{,}672}$$

$$Res = 2596{,}190832$$

$$ho = \frac{jHK}{D}\left[\frac{c\ x\ \mu}{k}\right]\text{^}0{,}33$$

$$Rc = \frac{D\ x\ Gt}{\mu} \qquad D = 1{,}37\ tabel\ 10$$

$$Rc = 5843{,}76$$

$$hi = \frac{jHK}{D}\left[\frac{c\ x\ \mu}{k}\right]\text{^}0{,}33$$

$$\text{hio} = hi\frac{ID}{OD}$$

Uc (clean overall coefficient)

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

Uc= 98.97690338 btu/hr.ft2.F

dirt factor, Rd

$$Rd = \frac{Uc - Ud}{Uc \times Ud}$$

Rd= −0,0101 btu/hr.ft2.F

APPENDIX OF CALCULATION DATA 843

TABLE 10. HEAT EXCHANGER AND CONDENSER TUBE DATA

Tube OD, in.	BWG	Wall thickness, in.	ID, in.	Flow area per tube, in.²	Surface per lin ft, ft²		Weight per lin ft, lb steel
					Outside	Inside	
½	12	0.109	0.282	0.0625	0.1309	0.0748	0.493
	14	0.083	0.334	0.0876		0.0874	0.403
	16	0.065	0.370	0.1076		0.0969	0.329
	18	0.049	0.402	0.127		0.1052	0.258
	20	0.035	0.430	0.145		0.1125	0.190
¾	10	0.134	0.482	0.182	0.1963	0.1263	0.965
	11	0.120	0.510	0.204		0.1335	0.884
	12	0.109	0.532	0.223		0.1393	0.817
	13	0.095	0.560	0.247		0.1466	0.727
	14	0.083	0.584	0.268		0.1529	0.647
	15	0.072	0.606	0.289		0.1587	0.571
	16	0.065	0.620	0.302		0.1623	0.520
	17	0.058	0.634	0.314		0.1660	0.469
	18	0.049	0.652	0.334		0.1707	0.401
1	8	0.165	0.670	0.355	0.2618	0.1754	1.61
	9	0.148	0.704	0.389		0.1843	1.47
	10	0.134	0.732	0.421		0.1916	1.36
	11	0.120	0.760	0.455		0.1990	1.23
	12	0.109	0.782	0.479		0.2048	1.14
	13	0.095	0.810	0.515		0.2121	1.00
	14	0.083	0.834	0.546		0.2183	0.890
	15	0.072	0.856	0.576		0.2241	0.781
	16	0.065	0.870	0.594		0.2277	0.710
	17	0.058	0.884	0.613		0.2314	0.639
	18	0.049	0.902	0.639		0.2361	0.545
1¼	8	0.165	0.920	0.665	0.3271	0.2409	2.09
	9	0.148	0.954	0.714		0.2498	1.91
	10	0.134	0.982	0.757		0.2572	1.75
	11	0.120	1.01	0.800		0.2644	1.58
	12	0.109	1.03	0.836		0.2701	1.45
	13	0.095	1.06	0.884		0.2775	1.28
	14	0.083	1.08	0.923		0.2839	1.13
	15	0.072	1.11	0.960		0.2896	0.991
	16	0.065	1.12	0.985		0.2932	0.900
	17	0.058	1.13	1.01		0.2969	0.808
	18	0.049	1.15	1.04		0.3015	0.688
1½	8	0.165	1.17	1.075	0.3925	0.3063	2.57
	9	0.148	1.20	1.14		0.3152	2.34
	10	0.134	1.23	1.19		0.3225	2.14
	11	0.120	1.26	1.25		0.3299	1.98
	12	0.109	1.28	1.29		0.3356	1.77
	13	0.095	1.31	1.35		0.3430	1.56
	14	0.083	1.33	1.40		0.3492	1.37
	15	0.072	1.36	1.44		0.3555	1.20
	16	0.065	1.37	1.47		0.3587	1.09
	17	0.058	1.38	1.50		0.3623	0.978
	18	0.049	1.40	1.54		0.3670	0.831

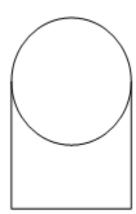
10.3.5 Storage Syngas

Fungsi : Untuk penyimpan Gas Hidrogen

Tipe : *Sperichal*

Bahan : Carbon Steel (SA-515), Grade 55 C-Si

Gambar :



Data :

- Laju alir massa gas masuk : 2099.09 kg/jam
- Densitas gas : 0,0052 lb/ft^3
- Temperatur masuk : 30℃ = 303,15 K
- Tekanan : 25,325 bar
- Lama Penyimpanan : 1 hari = 24 jam

Menghitung Volume Gas

Diket : n = 75,34934 mol

R= 83,14 cm3.bar/mol k

T = 30°C

P = 25,325 bar

$$PV = n.R.T$$

$$V = \frac{n.R.T}{P}$$

$$V = \frac{75{,}34934\ mol\ x\ 83{,}14\ cm3.\frac{bar}{mol}.K\ x\ 303{,}15\ K}{25{,}325\ bar}$$

V = 74989 cm^3

V = 0,07489 m^3

Faktor Keamanan 20%

0,8 Vt = Vg

Vt = 0,07489 : 0,8

Vt = 0.093736 m^3

Mencari Dimensi Tangki

r= ½ D

$$\boldsymbol{Vt = \frac{4}{3}\pi r^3}$$

$$\boldsymbol{Vt = \frac{4}{3}\pi(\frac{1}{2}D)^3}$$

$$\boldsymbol{D^3 = \frac{Vt}{0{,}5233}}$$

$$D = \sqrt[3]{\frac{0,093736}{0,523333}}$$

$$D = \sqrt[3]{0,178913}$$

$$D = 0,56672$$

Menghitung tebal dinding

Tekanan desain, P : 25 atm = 367,3975 psi

Jari-jari tangki, R : 1,133449 m = 44.62387 in

Allowable stress, S : 13700 psi

Efisiensi pengelasan, E : 0,85

Faktor korosi yang diizinkan : 0,05

TABLE 18.4. Formulas for Design of Vessels under Internal Pressure[a]

Item	Thickness t(in.)	Pressure p(psi)	Stress S(psi)	Notes
Cylindrical shell	$\frac{PR}{SE-0.6P}$	$\frac{SEt}{R+0.6t}$	$\frac{P(R+0.6t)}{t}$	$t \le 0.25D, P \le 0.385SE$
Flat flanged head (a)	$D\sqrt{0.3P/S}$	$t^2 S/0.3D^2$	$0.3D^2 P/t^2$	
Torispherical head (b)	$\frac{0.885PL}{SE-0.1P}$	$\frac{SEt}{0.885L+0.1t}$	$\frac{P(0.885L+0.1t)}{t}$	$r/L = 0.06,\ L \le D+2t$
Torispherical head (b)	$\frac{PLM}{2SE-0.2P}$	$\frac{2SEt}{LM+0.2t}$	$\frac{P(LM+0.2t)}{2t}$	$M = \frac{3+(L/r)^{1/2}}{4}$
Ellipsoidal head (c)	$\frac{PD}{2SE-0.2P}$	$\frac{2SEt}{D+0.2t}$	$\frac{P(D+0.2t)}{2t}$	$h/D = 4$
Ellipsoidal head (c)	$\frac{PDK}{2SE-0.2P}$	$\frac{2SEt}{DK+0.2t}$	$\frac{P(DK+0.2t)}{2Et}$	$K = [2+(D/2h)^2]/6,\ 2 \le D/h \le 6$
Hemispherical head (d) or shell	$\boxed{\frac{PR}{2SE-0.2P}}$	$\frac{2SEt}{R+0.2t}$	$\frac{P(R+0.2t)}{2t}$	$t \le 0.178D,\ P \le 0.685SE$
Toriconical head (e)	$\frac{PD}{2(SE-0.6P)\cos\alpha}$	$\frac{2SEt\cos\alpha}{D+1.2t\cos\alpha}$	$\frac{P(D+1.2t\cos\alpha)}{2t\cos\alpha}$	$\alpha \le 30°$

[a] Nomenclature: D = diameter (in.), E = joint efficiency (0.6–1.0), L = crown radius (in.), P = pressure (psig), h = inside depth of ellipsoidal head (in.), r = knuckle radius (in.), R = radius (in.), S = allowable stress (psi), t = shell or head thickness (in.).

$$t = \frac{PR}{2SE - 0,2P} + C$$

t = 0.756165184 in