BAB X. TUGAS KHUSUS

10.1 Pendahuluan

Industri kimia merupakan industri yang mengolah bahan baku menjadi produk dengan memanfaatkan proses-proses kimia. *Dimethyl ether* merupakan salah satu produk yang dihasilkan dari proses kimia. *Dimethyl ether* dapat dibuat melalui tiga tahapan proses yaitu persiapan bahan baku, tahapan pe reaksi, dan tahapan pemurnian produk.

Proses pembuatan *dimethyl ether* dari *methanol* dilakukan dengan satu tahap reaksi, yaitu reaksi dehidrasi. Reaksi esterifikasi yaitu proses mereaksikan *mehtanol* dengan katalis silica alumina sehingga membentuk *dimethyl ether* pada suhu 250^0C dengan tekan 12 atm. Reaksi yang terjadi sebagai berikut :

- **Reaksi Dehidarasi**

$$2CH_3OH_{(l)} \Leftrightarrow CH_3OCH_{3\,(g)} + H_2O_{(g)}$$

(Metanol) (*Dimethyl ether*) (Air)

Perancangan pabrik dimethyl ether harus mempertimbangkan kebutuhan metanol di Indonesia, ketersediaan bahan baku, lahan, pemilihan proses, peralatan yang digunakan, serta pemasaran hasil produksi. Sebelum proses produksi berjalan, langkah awal yang terlebih dahulu dilakukanya itu membuat rancangan peralatan proses yang digunakan.

10.2 Ruang Lingkup Rancangan

Perancangan peralatan proses yang digunakan dalam produksi *dimethyl ether* terdiri dari perancangan reaktor, alat transportasi, alat perpindahan panas, dan alat pemisah. Reaktor merupakan tempat terjadinya reaksi kimia methanol dengan katalis silica alumina, sehingga menghasilkan dimethyl ether dengan air. Alat transportasi yang digunakan berupa pompa sedangkan alat transportasi fluida gas berupa kompressor. Adapun alat perpindahan panas meliputi heater, cooler dan kondensor. Rancangan alat pemisah meliputi vaporizer dan PSA(Pressure Swing Adsorbtion). Perancangan lengkap peralatan proses dilihat pada sub bab rancangan.

10.3 Rancangan

1 . Tangki Penyimpanan *Metanol*

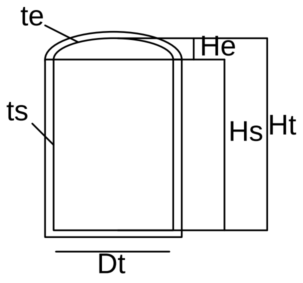
Fungsi : Untuk menyimpan bahan baku*metanol*

Tipe : Silinder vertikal dengan alas datar dan tutup *ellipsoidal*

Bahan : *High alloy steels*SA-240 304

Jumlah : 1 unit

Gambar :



Data :

- Laju alir : 11494.63731 kg/jam
- Densitas Campuran : 794.051 kg/m^3
- Temperatur : 30°C = 86 F
- Tekanan : 1 atm

Kapasitas Tangki, V_t

Lama penyimpanan = 7 hari = 168 jam

$$V_c = \frac{m}{\rho} \text{x t}$$

$$= \frac{11494.63731 kg\,/\,jam}{794.05 kg\,/\,m^3} \text{ x 168 jam}$$

$$\mathbf{= 2431.961549\ m^3}$$

Faktor keamanan 20 % (rule of thumb)

Maka,

$$Vt = \frac{Vc}{0{,}8}$$

$$= \frac{2431.961549 m^3}{0{,}8}$$

$$= 3039.951936 \text{ m}^3$$

$$= 803070.183 \text{ gal}$$

VESSEL (TANGKI PENYIMPANAN)

1. Untuk yang kurang dari 1000 gal, gunakan tangki vertikal dengan kaki-kaki.
2. Antara 1000 dan 10,000 gal, gunakan tangki horisontal dengan *support* beton.
3. Diatas 10,000 gal, gunakan tangki vertikal dengan pondasi beton.
4. Cairan mengacu ke *breathing losses* dapat disimpan dalam tangki dengan atap mengapung atau mengembang untuk konservasi.
5. *Freeboard* adalah 15% dibawah kapasitas 500 gal dan 10% diatas kapasitas 500 gal.

Dimensi Tangki,

- **Volume silinder, V_s**

$$V_s = \frac{\pi}{4}\ x\ D_t^2\ x\ H_s \qquad\qquad H_s = 1{,}5\ D_t$$

Maka,

$$V_s = \frac{\pi}{4}\ x\ \ 1{,}5\ D_t^3$$

- **Volume ellipsoidal, V_e**

$$V_e = 0{,}1308\ x\ D_t^3 \qquad\qquad H_e = 1/4\ D_t$$

- **Diameter tangki, D_t**

$$V_t = V_s + V_e$$

$$V_t = \left(\frac{\pi}{4}\ x\ \ 1{,}5 D_t^3\right) + (0{,}1308\ x\ D_t^3)$$

$$V_t = 1{,}1775\ x\ D_t^3$$

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

$$Dt = \sqrt[3]{\frac{Vt}{1{,}1775}}$$

$$= \sqrt[3]{\frac{3039.951936}{1{,}1775}} = \mathbf{13.7184\ M}$$

Tinggi tangki, H_t

- Tinggi silinder, H_s

$H_s = 1{,}5\ D_t = 20{,}5775$ m

- Tinggi *ellipsoidal*, H_e

$H_e = 1/4 D_t = 3{,}4296$ m

- Tinggi tangki, H_t

  $H_t = H_s + H_e$

  = 20,5775 m + 3,4296 m = **24,0071 m**
- **Tinggi Cairan, H_c**

  $$H_c = \frac{Volume\ Cairan}{Volume\ Tangki}\ x\ H_t$$

  Hc = 19,2057 m
- **Tekanan Cairan, P_c**

  $P_c = \rho\ .g\ .h_c$

  Pc $= 794{,}05\frac{Kg}{M3}\ x\ 9{,}8\ \frac{M}{s^2}\ x\ 19{,}2057\ m$

  Pc $= 149605{,}2475\frac{kg}{m.s^2}$

  = 1,4765 atm
- **Tekanan Disain, P_d**

  Pd = Pop + Pc

  =1 atm + 1,4765 atm

  = 2,4765 atm

  $= 36{,}3942\ psi$
- **Tebal dinding tangki, t_d**

  $$t_d = \frac{PR}{SE - 0.6P} + C \qquad (Walas, Tabel\ 18.3, hal\ 625)$$

- Tekanan desain, P : 36,3942psi
- Jari-jari tangki, R : 270,0464 in
- *Allowable stress*, S : 13700 psi (Peter, Tabel 4 Hal 538)
- Efisiensi pengelasan, E : 0,85 (Peter, Tabel 4 Hal 538)
- Faktor korosi yang diizinkan: 0,02 in/thn (Peter, Hal 542)
- Tahun digunakan : 10 tahun
- $t_d = \frac{36{,}3942\ Psi\ x\ 270{,}0464\ in}{(13700\ psi\ x\ 0{,}85)-(0.6\ x\ 36{,}3942\ psi)} + 0{,}02\frac{in}{tahun}\ x\ 10\ tahun$
- t_d = 1,0456 in = 0,0266 m

- **Tebal tutup *ellpsoidal*, t_e**

  $$t_e = \frac{0{,}885PD_t}{SE - 0{,}6\ P} + C \qquad \text{(Wallas, Tabel 18.4, Hal 537)}$$

$$t_e = \frac{0{,}885\ x\ 36{,}3942\ psi\ x\ 270{,}0464\ in}{(13700\ psi\ x\ 0{,}85) - (0{,}6\ x\ 36{,}3942\ psi)} + 0{,}02\frac{in}{tahun}x\ 10\ tahun$$

= 1,0442 in = 0,0265 m

2. Pompa

Fungsi : Mengalirkan *methanol* menuju vaporizer

Tipe : *Centrifugal pump*

Gambar :

Gambar 10.1 Aliranpompa (PM-101)

Data :

$$\frac{P_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a V_a^2}{2g_c} + \eta W_p = \frac{P_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b V_b^2}{2g_c} + h_f$$

- Laju alir massa, m : 10939,050kg/jam = 6,697lb/s
- Densitas , ρ : 878,091 kg/m^3 = 54,820lb/ft^3
- Viskositas , μ : 7,633cP = 18,465 lb/ft.hr
- Tinggi pompa terhadap cairan masuk, Z_a : 0 m = 0ft
- Tinggi pompa terhadap cairan keluar, Z_b : 7,91 m = 225,95ft
- Panjang pipa hisap, L_s : 3 m = 9,84ft
- Panjang pipa buang, L_d : 8 m = 26,24ft
- Faktor keamanan 10% (Peter's, Tabel 6)

PROCESS DESIGN DEVELOPMENT 37

TABLE 6
Factors in equipment scale-up and design

Type of equipment	Is pilot plant usually neces-sary?	Major variables for operational design (other than flow rate)	Major variables characterizing size or capacity	Maximum scale-up ratio based on indi-cated char-acterizing variable	Approxi-mate recom-mended safety or over-design factor, %
Agitated batch crystallizers	Yes	Solubility-temperature relationship	Flow rate Heat transfer area	>100:1	20
Batch reactors	Yes	Reaction rate Equilibrium state	Volume Residence time	>100:1	20
Centrifugal pumps	No	Discharge head	Flow rate Power input Impeller diameter	>100:1 >100:1 10:1	10

Laju alir volumetrik, Q_v

$$Q_p = \frac{m}{0{,}9}$$

$$= \frac{6{,}697 \text{ lb/s}}{0{,}9}$$

$$= 7{,}441 \text{lb/s}$$

$$Q_v = \frac{Qp}{\rho}$$

$$= \frac{7{,}441 \text{ lb/s}}{54{,}819 \text{ lb/ft}^3}$$

$$= 0{,}136 \text{ ft}^3\text{/s} = 60{,}929 \text{ gal/min}$$

Diameter optimum, D_{opt}

Asumsi aliran turbulen

$$D_{opt} = 3{,}9 * Qv^{0{,}45} * \rho^{0{,}13} \qquad \text{(Peter, Pers 14.15)}$$

making design estimates:

For turbulent flow ($N_{Re} > 2100$) in steel pipes

$$D_{i,opt} = 3.9 q_f^{0.45} \rho^{0.13} \tag{15}$$

For viscous flow ($N_{Re} < 2100$) in steel pipes

$$D_{i,opt} = 3.0 q_f^{0.36} \mu_c^{0.18} \tag{16}$$

Peter, Hal 496

$$D_{opt} = 3{,}9 \, x 0{,}136^{0{,}45} \, x \, 54{,}820^{0{,}13}$$

$$= 2{,}672 \text{ in}$$

Berdasarkan Tabel 11 Kern, diperoleh pipa baja dengan ukuran sebagai berikut :

	Suction (a)			**Discharge (b)**		
IPS	3 in Sch 40					
	in	ft	m	in	ft	m
ID	3,500	0,292	0,089	3,500	0,292	0,089
OD	3,068	0,256	0,078	3,068	0,256	3,068
a"			0,0513	ft^2		

Kecepatan aliran, V

Va = Vb, karena ukuran pipa hisap dan pipa buang sama

$$V = \frac{Qv}{a''}$$

$$= \frac{0{,}136\ ft^3/s}{0{,}0513\ ft^2}$$

$$= 2{,}646\ ft/s\ \ = 9525{,}73 ft/jam$$

$$\frac{V^2}{2gc} = \frac{7{,}0015\ ft/s}{2\ x 32{,}17\ lbmft/s^2\ \ Ibf}$$

$$= 0{,}1088\ ft\text{-}lb_f/lb$$

Bilangan Reynolds, N_{Re}

$$N_{Re} = \frac{\rho\ x\ V\ x\ D}{\mu}$$

SIGNIFICANCE OF DIMENSIONLESS GROUPS.[23] The three dimensionless groups in Eq. (9.14) may be given simple interpretations. Consider the group $nD_a^2\rho/\mu$. Since the impeller tip speed u_2 equals $\pi D_a n$,

$$\boxed{N_{Re} = \frac{nD_a^2\rho}{\mu}} = \frac{(nD_a)D_a\rho}{\mu} \propto \frac{u_2 D_a \rho}{\mu} \tag{9.17}$$

and this group is proportional to a Reynolds number calculated from the diameter and peripheral speed of the impeller. This is the reason for the name of the group.

Mc,Cabe Hal 249

$$N_{Re} = \frac{54{,}820\ \ lb/ft^3\ x\ 9525{,}731\ ft/jam\ x\ 0{,}256\ ft}{18{,}465\ lb/ft.jam}$$

$$= 7230{,}289\ (>4000\ aliran\ turbulen)$$

Rugi Gesek

- **Pipa hisap (*suction*)**

- **Rugi gesek akibat gesekan dengan kulit pipa**

$$h_{fsa} = f\ \frac{\Delta L}{r_H}\ \frac{V^2}{2gc} \qquad \text{(McCabe, Pers 5.56)}$$

104 FLUID MECHANICS

where D_i and D_o are the inside and outside diameters of the annulus, respectively. The equivalent diameter of an annulus is therefore the difference of the diameters. Also, the equivalent diameter of a square duct with a width of side b is $4(b^2/4b) = b$.

The hydraulic radius is a useful parameter for generalizing fluid-flow phenomena in turbulent flow. Equation (5.7) can be so generalized by substituting $4r_H$ for D or $2r_H$ for r_w:

$$\boxed{h_{fs} = \frac{\tau_w}{\rho r_H}\Delta L = \frac{\Delta p_s}{\rho} = f\frac{\Delta L}{r_H}\frac{\bar{V}^2}{2g_c}} \qquad (5.56)$$

$$N_{Re} = \frac{4r_H\bar{V}\rho}{\mu} \qquad (5.57)$$

Mc.Cabe

$$r_H = \frac{ID}{4}$$ McCabe, Hal 103

Thus, for the special case of a circular tube, the hydraulic radius is

$$\boxed{r_H = \frac{\pi D^2/4}{\pi D} = \frac{D}{4}}$$ Mc.Cabe Hal 103

$$r_H = \frac{0{,}256\ \text{ft}}{4} = 0{,}064\text{ft}$$

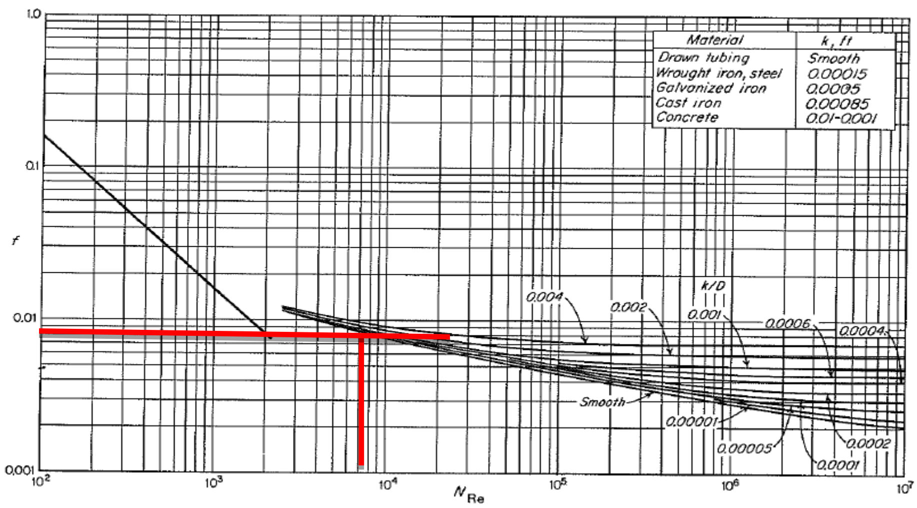
Nre = 7230,289

Material pipa yang digunakan adalah *wrought iron steel* :

k = 0,00015 ft Mc.Cabe Fig 5.9

k/D = 0,00587

f = 0,0089 Mc.Cabe Fig. 5.9



$$h_{fsa} = \frac{0{,}0089\text{x } 9{,}84\text{ ft x } 0{,}109\text{ft - lb}_f\text{/lb}}{0{,}064\ ft}$$

$= 0{,}149$ ft-lb$_f$/lb

- **Rugi gesek akibat *fitting* (hff)**

$$h_{ffa} = Kf \frac{V^2}{2gc}$$ Mc.CabePers 5.67

EFFECT OF FITTINGS AND VALVES. Fittings and valves disturb the normal flow lines and cause friction. In short lines with many fittings, the friction loss from the fittings may be greater than that from the straight pipe. The friction loss h_{ff} from fittings is found from an equation similar to Eqs. (5.59) and (5.65):

$$\boxed{h_{ff} = K_f \frac{\bar{V}_a^2}{2g_c}} \qquad (5.67)$$

Mc.Cabe Hal 107

where K_f = loss factor for fitting
$\bar{V}_a$ = average velocity in pipe leading to fitting

Kf *gate valve* = 0,2 x 1 = 0,2 Mc.Cabe, Tabel 5.1

Kf = 0,2

TABLE 5.1
Loss coefficients for standard threaded pipe fittings†

Fitting	K_f
Globe valve, wide open	10.0
Angle valve, wide open	5.0
Gate valve	
Wide open	0.2
Half open	5.6
Return bend	2.2
Tee	1.8
Elbow	
90°	0.9
45°	0.4

† From J. K. Vennard, in V. L. Streeter (ed.), *Handbook of Fluid Dynamics*, McGraw-Hill Book Company, New York, 1961, p. 3–23.

$$h_{ffa} = 0{,}2 \times 0{,}109 \text{ft} - \text{lb}_f/\text{lb}$$

= 0,0218 ft.lbf/lb

- **Pipa buang (*discharge*)**

- **Rugi gesek akibat gesekan dengan kulit pipa**

$$H_{fsb} = f \frac{\Delta L}{r_H} \frac{V^2}{2gc}$$ (McCabe, Pers 5.56)

$$r_H = \frac{ID}{4}$$ (McCabe, Hal 103)

$$r_H = \frac{0{,}256 \text{ ft}}{4} = 0{,}064 \text{ft}$$

Nre = 7230,289

Material pipa yang digunakan adalah *wrought iron steel* :

k = 0,00015 ft Mc.Cabe Fig 5.9

k/D = 0,00587

f = 0,0089 Mc.Cabe Fig. 5.9

$$h_{fsb} = \frac{0{,}0089 \text{ x } 26{,}24 \text{ ft x } 0{,}109\text{ft - lb}_f\text{/lb}}{0{,}064\ ft}$$

$= 0{,}3976$ ft.lb$_f$/lb

- **Rugi gesek akibat *fitting*(hff)**

$H_{ffb} = Kf \dfrac{V^2}{2gc}$ Mc.CabePers 5.67

Kf elbow = 0,9 x 2 = 1,8 Mc.Cabe, Tabel 5.1

Kf Globe valve = 10

Kf = 11,8

H_{ffb} = 11,8 x 0,109 ft.lb$_f$/lb

= 1,284ft.lb$_f$/lb

Sehingga, rugi gesek total (hf $_{total}$) :

hf_{total} = hf suction + hf dischage

= 1,853 ft.lb$_f$/lb

Daya Pompa (BHP)

Daya pompa dapat dihitung dengan menggunakan Persamaan Bernoulli (McCabe, Pers. 4.32):

$$\frac{P_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a V_a^2}{2g_c} + \eta W_p = \frac{P_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b V_b^2}{2g_c} + h_f$$

Atau

$$\eta W_p = \left(\frac{P_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b V_b^2}{2g_c}\right) - \left(\frac{P_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a V_a^2}{2g_c}\right) + h_f$$

The mechanical energy delivered to the fluid is, then, ηW_p, where $\eta < 1$. Equation (4.29) corrected for pump work is

$$\frac{p_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a \bar{V}_a^2}{2g_c} + \eta W_p = \frac{p_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b \bar{V}_b^2}{2g_c} + h_f \qquad (4.32)$$

Equation (4.32) is a final working equation for problems on the flow of incompressible fluids. Mc.Cabe

Dimana

P_a = P_b

V_a = V_b

ρ_a $= \rho_b$

g/g_c $= 1$

α_a $= \alpha_b$

Q = 60,944 gal/min

η = 50 %

(Peters, Fig. 14.37)

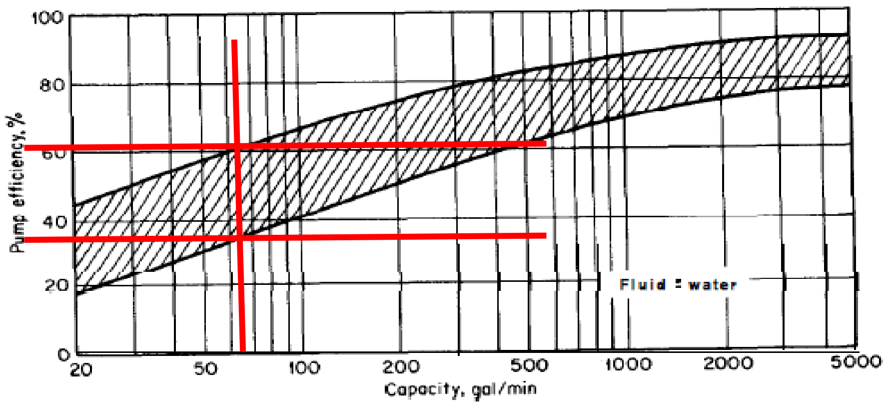


FIGURE 1437
Efficiencies of centrifugal pumps.

Sehingga persamaan di atas dapat disederhanakan menjadi :

$$\eta W_p = (Zb - Za) + hf$$

$$Wp = \frac{(Zb - Za) + hf}{\eta}$$

= 55,594 ft.lb$_f$/lb

$$BHP = \frac{Wp \text{ x } m}{550}$$

$$= \frac{55{,}594 \text{ ft.lbf/lb x } 7{,}411 \text{ lb/s}}{550}$$

= 0,7522 HP

Daya motor (MHP)

$$MPH = \frac{BHP}{\eta}$$

η = 80 % (Peters, Fig 14.38)

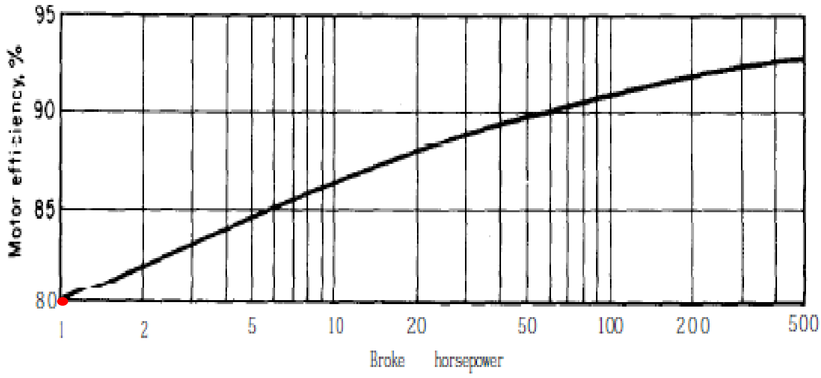


FIGURE 1438
Efficiencies of three-phase motors.

$$MPH = \frac{0{,}752\ HP}{80\%}$$

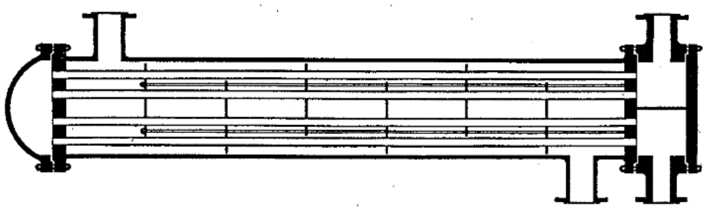
$= 0{,}9402$ HP

3. *Heater*

Fungsi : Memanaskan *fatty acid*yang di alirkan ke reaktor

Tipe :1-2 *Sheel and Tube Heat Exchanger*

Jumlah : 1



Gambar 10.2*Sheel and Tube Heat Exchanger*

1. Data dan Kondisi Operasi

A. Beban Panas (Q) = 3.081.148,7169 kj/jam = 2.920.365,1334 btu/jam

B. Fluida Panas = Steam

Laju Alir (W_t) = 1.755,8404kg/jam = 3.870,9608lb/jam

T_1 = 242 ºC = 467,6 ºF

T_2 = 242 ºC = 467,6 ºF

C. Fluida Dingin = *Fatty Acid*

Laju Alir (W_s) = 10.939,050kg/jam = 24.116,4484lb/jam

t1 = 30 ºC = 86 ºF

t2 = 120 ºC = 248 ºF

2. Δt & LMTD

Fluida Panas (F)	Temperatur	Fluida Dingin (F)	Selisih	
467,6	Tinggi	248	219,6	ΔT1
467,6	Rendah	86	381,6	ΔT2

$$LMTD = \frac{(\Delta T_2 - \Delta T_1)}{In\frac{\Delta T_2}{\Delta T_1}}$$

$$= \frac{(381{,}6 - 219{,}6\quad)}{In\frac{381{,}6}{219{,}6}} = 293{,}18\ °F$$

Faktor koreksi LMTD

$$R = \frac{T_1 - T_2}{t_2 - t_1}$$ (D.Q Kern: Pers. 5.14hal. 828)

$$= \frac{(467{,}6 - 467{,}6)°F}{(248 - 86)°F} = 0$$

$$S = \frac{t_2 - t_1}{T_1 - t_1}$$

$$= \frac{(248 - 86)°F}{(467{,}6 - 86)°F} = 0{,}424$$

Diasumsikan *Heat ExchangerHeater*(He-101) merupakan HE dengan 4 *Shell Pass* dan 8 *Tube Pass*. Dari nilai R dan S, maka Faktor Koreksi dapat diperoleh dari gambar 21 D.K. QERN adalah sebagai berikut:

F_T = 0,98

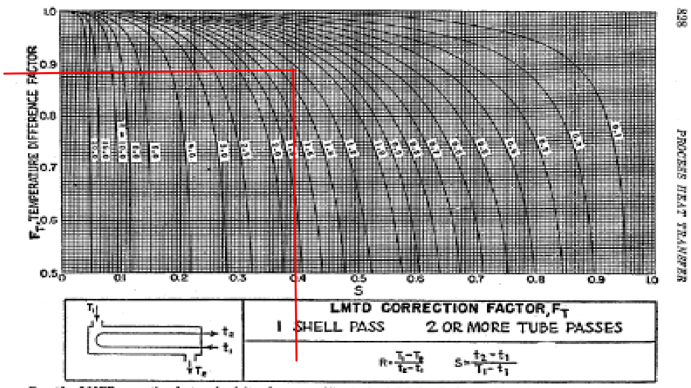


FIG. 18. LMTD correction factors for 1-2 exchangers. (Standards of Tubular Exchanger Manufacturers Association, 2d ed., New York, 1949.)

Sehingga :

ΔT_{LMTD} = LMTD x F_T (D.Q Kern: Pers. 7.42hal. 828)

= 293,18°F x 0,98 = 287,314°F

3. Luas Area Perpindahan Panas, A

$$A = \frac{Q}{U_D \; x \; \Delta T_{LMTD}}$$ (D.Q Kern, pers. 7.6 hal 140)

Berdasarkan Tabel 8, D.Q Kern Hal 840, diperoleh :

Ud = 33 Btu/jam.ft^2.F

Heaters

Hot fluid	Cold fluid	Overall U_D
Steam	Water	200–700§
Steam	Methanol	200–700§
Steam	Ammonia	200–700§
Steam	Aqueous solutions:	
Steam	Less than 2.0 cp	200–700
Steam	More than 2.0 cp	100–500§
Steam	Light organics	100–200
Steam	Medium organics	50–100
Steam	Heavy organics	6–60
Steam	Gases	5–50¶

* *Light organics* are fluids with viscosities of less than 0.5 centipoise and include benzene, toluene, acetone, ethanol, methyl ethyl ketone, gasoline, light kerosene, and naphtha.

† *Medium organics* have viscosities of 0.5 to 1.0 centipoise and include kerosene, straw oil, hot gas oil, hot absorber oil, and some crudes.

‡ *Heavy organics* have viscosities above 1.0 centipoise and include cold gas oil, lube oils, fuel oils, reduced crude oils, tars, and asphalts.

§ Dirt factor 0.001.

‖ Pressure drop 20 to 30 psi.

¶ These rates are greatly influenced by the operating pressure.

$$A = \frac{}{33 \text{ Btu/jam.ft}^2\text{.F} \; x \; 293{,}18°\text{F}}$$

= 301,850 ft^2

Nilai A >200 ft^2 maka digunakan tipe perpindahan panas jenis *shell and tube.*

Dalam Perancangan ini digunakan *heater* dengan spesifikasi :

Diameter luar tube (OD)	= ¾ in
Jenis tube	= 18 BWG
Pitch (Pt)	= 15/16 in Triangular Pitch
Panjang tube (L)	= 12 ft
a”	= 0,1963 ft^2/ft (Tabel 10, DQ. Kern)

4. Menentukan Jumlah Tube

Jumlah tube :

$$N_t = \frac{A}{L \ x \ a''}$$

$$= \frac{301{,}850 \ ft^2}{12 \ ft x \ 0{,}1963 \frac{ft^2}{ft}} = 128{,}142 \approx 129 \text{ buah}$$

Koreksi :

$$A = Nt \ x \ L \ x \ a''$$

$= 129 \text{ x } 12 \text{ x } 0{,}1963$

$= 301{,}8504 \text{ ft}^2$

$$U_d = \frac{Q}{A \ x \ \Delta t \ LMTD}$$ (D.Q Kern, pers. 7.6 hal 140)

$$= \frac{2.920.365{,}1334 \text{ Btu/jam}}{301{,}850 \text{ft}^2 \ x \ 293{,}18°\text{F}}$$

$= 33 \text{ Btu/jam.ft}^2\text{.F}$

3. Spesifikasi *Heat Exchanger*

Berdasarkan Tabel 10 dan 9 D.Q Kern, diperoleh spesifikasi perancangan *Heat Exchanger* tipe *Shell and Tube* dengan :

Shell side		***Tube side (Tabel.10 DQ kern)***	
Diameter dalam (ID)	15,25	Diameter dalam (OD) in	0.75
Baffle space (B)=0,2xID	3,05	Diameter luar(iD) in	0,652
Passes (n)	1	BWG	18
		Pitch (Pt)	0,9375
		Passes (n)	2
		Panjang (ft)	12
		Jumlah Tube (N)	129

Shell, Fluida Panas	**Tube, Fluida Dingin**
*4. **Flow Area*** $a_s = \frac{IDxC' xB}{144P_T}$ (D.Q Kern: pers. 7.1, hal 138)	***6. Flow Area*** at' = 0,3340 in (D.Q Kern, Table 10 hal 843) $a_t = \frac{N_t \ x \ at'}{144 \ n}$ (D.Q Kern: pers 7.48, hal 111)

$= \dfrac{15{,}25 \text{ in x } 0{,}1875 \text{ in x } 3{,}050 \text{ in}}{144 \text{ x } 0{,}9375}$ = 0,0646 ft^2	$= \dfrac{129 \;\; x \;\; 0{,}334 in^2}{144 \, x 2}$ = 0,149 ft^2
7. Mass Velocity $G_s = \dfrac{Ws}{a_s}$ (D.Q Kern: pers 7.2, hal 138) $= \dfrac{3.870{,}9608 \text{ lb/h}}{0{,}0646 \text{ ft}^2}$ = 59.921,4 lb/hr ft^2	***5. Mass Velocity*** $Gt = \dfrac{Wt}{a_t}$ (D.Q Kern: pers 7.2, hal 138) $= \dfrac{24.116{,}4484 \text{ lb/h}}{0{,}149 \text{ ft}^2}$ = 161.201,716 lb/hr ft^2
6. Reynold Number $D_e = 0{,}55 \; in$ = 0,04583 ft µ = 0,12 Cp = 0,2904 lb/ft.h(Fig. 14) $Re_s = \dfrac{\text{De x Gs}}{\mu}$ $= \dfrac{0{,}04583 \text{ ft x } 59.921{,}4 \text{ lb/hr ft}^2}{0{,}2904 lb/h.ft}$ = 9.457,284	***8.Reynold Number*** µ = 0,131 Cp = 0,317 lb/ft.h ID = 0,652 in =0,0543 ft $Re_t = \dfrac{\text{D x Gt}}{\mu}$ $= \dfrac{0{,}0543 \text{ ft x } 161.201{,}716 \text{ lb/hr ft}^2}{0{,}317 lb/h.ft}$ = 27.672,049
7. Faktor Perpindahan Panas(J_{Hs}) Dari gambar 28 D.Q.KERN maka didapatkan nilai Jh sebagai berikut: Jh = 35	**9.Faktor Perpindahan Panas(J_{Ht})** L = 12 ft D = 0,0543 ft L/D = 220,859 Dengan memplotkan NRe dengan L/D ke gambar 24 D.Q.KERN maka didapatkan nilai Jh sebagai berikut: Jh = 50
8. Koefisien Perpindahan Panas Pada T_c = 305,6 °F c = 0,45 Btu/lb°F (D.Q Kern, Fig. 2 Hal 804) k = 0,0163 Btu/ft.hr.°F (D.Q Kern, Tabel 4) = 1,99	**10. Koefisien Perpindahan Panas** Pada Tc= 167 °F C = 0,43 Btu/lb°F (Perrys, Tabel 2-197) k = 0,0925 Btu/ft.hr.°F (D.Q Kern, Tabel 5) $\left(c.\dfrac{\mu}{k}\right)^{\frac{1}{3}} = \left(0{,}43 \text{ x } \dfrac{0{,}317 lb/\, ft.h}{0{,}0925 \text{Btu/ft.hr.}^0 \text{ F}}\right)^{1}$ = 1,137
9. *Inside Film Coefficient* (h_o)	**11. *Inside Film Coefficient* (h_{io})**

Karna di *shell*adalah fluida steam, maka nilai h_o= 1500	$\frac{h_i}{\phi_s} = jH.\frac{k}{D_e}.\left(\frac{C.\mu}{k}\right)^{1/3}$ $= 1\ x\ \frac{0{,}0925 Btu/ft.hr.^o F}{0{,}0543\ ft} 1{,}137$ $= 96{,}857 Btu/hr.ft2.^o F$ **Koreksi H_{io} ke permukaan OD** $h_{i0} = hi.\frac{ID}{OD}.$ $= 96{,}857 Btu/hr.ft2.^o F\ x\ \frac{0{,}652}{0{,}75}$ $= 80{,}714 Btu/hr.ft2.^o F$

10. Clean overall coefficient U_c

$$U_C = \frac{h_{io}\, x\, h_o}{h_{io} + h_o}$$

$$= \frac{80{,}714 x\, 1500}{80{,}714 + 1500}$$

$$= 76{,}593\ btu / hr.ft^{2.}{}^{\circ}F$$

11. Dirty Factor, R_d

$$Rd = \frac{U_C - U_D}{U_C\ x U_D} = \frac{76{,}593\, btu/hr.ft^2\,{}^{\circ}F - 33\, btu/hr.ft^2\,{}^{\circ}F}{76{,}593\, btu/hr.ft^2\,{}^{\circ}F\ x\, 33\, btu/hr.ft^2\,{}^{\circ}F}$$

$$= 0{,}01725\, btu/hr.ft^2\,{}^{\circ}F$$

12. Pressure Drop, ΔP	
Re_s = 9.457,283 f = 0,0024ft^2/in^2 (Kern: *fig.* 29, hal 839) s = 1 (engineertoolbox.com) $(N+1) = Nx\frac{L}{B}$ (D.Q Kern, pers. 7.43 hal 147) $= 12x\frac{12}{3{,}050} = 47{,}213$ $Ø_s$ = 1 lb/ft h $\Delta P_s = \frac{f\ x G_s^2 x D_s\ x N+1}{5{,}22\, x 10^{10}\ D_s x \phi_s}$ $= \frac{0{,}0024\, x\, 3870{,}961^2\, x 1{,}271\, x\, 47{,}213}{5{,}22\, x 10^{10}\ x 1{,}271 x 1}$	Re_t = 27.672,049 f = 0,0018ft^2/in^2 (Kern: *fig.* 29, hal 836) s =0,9264 $Ø_s$ = 1 lb/ft h $\Delta P_t = \frac{f\ x G_t^2\, x\, Lx\, n}{5{,}22\, x 10^{10}\ Dt\ x\ s\ x \phi_t}$ $= \frac{0{,}0018\, x 161.201{,}716^2\, x 12\, x\, 2}{5{,}22\, x 10^{10}\ x 0{,}0543 x 1 x 1}$ = 0,0543 psi • ΔP total Gt = 5071,956 lb/hr ft^2

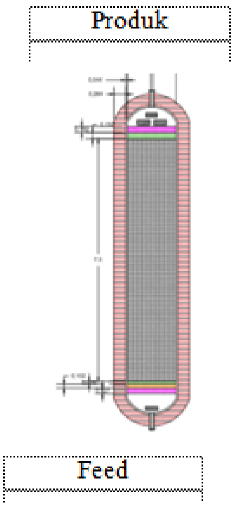
= 0,0009 psi	$\Delta P_r = \frac{4\,x\,n}{s} x \frac{V^2}{2g}$ $\frac{V^2}{2g} = 0{,}0033$ (Kern: *fig.* 27, hal 837) $\Delta P_r = \frac{4\,x 2 x 0{,}0033}{1} = 0{,}0285\,psi$ $\Delta P_t = \Delta P_t + \Delta P_r =$ 0,456 psi

4. Reaktor (RC-201)

Fungsi : MereaksikanFame dengan hidrogen menjadi fatty alcohol

Tipe : Reaktor Fixed Bed

Gambar :



Gambar 10.3 Reaktor Hidrogenasi

Data :

Data :

- Lajualirumpan, m = 18391.41969 kg/jam
- Lajualir molar, F_{AO} = 576.398364kmol/jam
- Densitas Katalis = 780 kg/m^3
- Temperatur, T = 250°C
- Tekanan, P = 12atm
- Waktu operasi,τ = 1 jam

1. Volume Katalis

Perbandingan umpan dan katalis (2:1)
X =2/1 x 18391,41969
X = 36782,83939 Kg
Volume Katalis = X/densitas
Volume Katalis = 36782,83939 Kg/780 kg/m^3
Volume katalis = 47,15749 m^3
Volume Katalis = Volume Reaktor = 47,15749 m^3

2. Perancanganreaktor

Faktor keamanan reaktor 20%

Tujuan factor keamanan dalam merancang tangki adalah menyediakan ruang atau space untuk mengantisipasi pengaruh udara dengan bahan didalamnya

Maka V_R= 80% x Vt

Vt= 47,15749m^3 / 0,8

Vt= 58,946858 m^3

a) Dimensireaktor

- **Diameter Tangki**

- **Volume silinder (Vs)**

$$\boxed{\begin{aligned} Vs &= \frac{\pi}{4} \times D_r^2 \times Hs \\ Vs &= \frac{\pi}{4} \times D_r^2 \times 1{,}5Dr \\ Vs &= \frac{\pi}{4} \times 1{,}5D_r^3 \end{aligned}}$$

DimanaHs=1,5Dr

- **Volume ellipsoidal (Ve)**

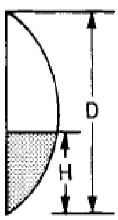
Ve=0,1309 x Dr^3 He= ¼ Dr

Hemispherical head

$S = 1.571D^2$
$V = (\pi/3)H^2(1.5D - H)$
$V_0 = (\pi/12)D^3$
$V/V_0 = 2(H/D)^2(1.5 - H/D)$

Ellipsoidal head $\boxed{(h = D/4)}$

$S = 1.09D^2$
$\boxed{V_0 = 0.1309D^3}$
$V/V_0 = 2(H/D)^2(1.5 - H/D)$



WallasTabel 18.5, hal650

- **Diameter reaktor, D_r**

$$Vr = Vs + 2Ve$$

$$Vr = (\frac{\pi}{4} \times 1{,}5D_r^3) + 2(0{,}1309D_r^3)$$

$$Vr = (1{,}4404D_r^3)$$

$$Dr = \sqrt[3]{Vr / 1{,}4404}$$

58,946858

-

-

- **TinggiSilinder(Hs)**

  Hs=1,5Dr

  Hs=1,5 x 3,446 m

  Hs= 5,169126 m

- **TinggiElipsoidal (He)**

  He= ¼ Dr

  He= ¼ x 3,446 m

  He= 0,86152 m

- **TinggiReaktor (Hr)**

  Hr=Hs+2He

  Hr= 5,169m + (2 x 0,8615m)

  Hr= 6,892168 m

Reaktor direncanakan diletakkandiatas kaki penyangga yang terbuatdaribetondengantinggi 3 meter sehingga tinggi total (Ht)

  Ht= 6,892168m+3m

  Ht= 9,892168 m

- **TekananDesain (Pd)**

  Pd= 12,15896442 bar = 176,3508 psia

- **TebalDindingTangki (Td)**

TABLE 18.3. Formulas for Design of Vessels under Internal Pressure[a]

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)	$\frac{PD}{2(SE-0.6P)\cos\alpha}$	$\frac{2SEt\cos\alpha}{D+1.2t\cos\alpha}$	$\frac{P(D+1.2t\cos\alpha)}{2t\cos\alpha}$	$\alpha \le 30°$

[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.).
Note: Letters in parentheses in the first column refer to Figure 18.16.

$(Wallas, tabel\ 18.3\ hal\ 649)$

(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	$\boxed{12{,}900}$	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	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			

$(Wallas, tabel\ 18.4\ hal\ 650)$

TekananDesain, P	= 176,3508psi	
Jari-JariTangki, R= 1,723m= 67,8363in		
Allowable Stress, S	= 13.700 psi	(Walas, Tabel 18.4)
EfisiensiPengelasan, E	= 0.85	(Petter, Tabel 4 hal 538)
Faktorkorosi, C	= 0.002in/tahun	(Perry's tabel 23-2)

$$t_d = \frac{PR}{SE - 0.6P} + C \qquad (Walas, Tabel\ 18.3)$$

$$t_d = \frac{176{,}3508\ \text{psi} \times 67{,}8363\ \text{in}}{(13.700\ \text{psi} \times 0.85) - (0.6 \times 176{,}3508\ \text{psi})} + 0.002\ \text{in/tahun} \times 10\ \text{tahun}$$

$$= 1.24836\ \text{in}$$

$$= 31{,}7083\ \text{m}$$

- **TebalDindingEllipsoidal (Te)**

$$t_e = \frac{PD_t}{2SE - 0.2P} + C$$

$$t_e = \frac{176{,}3508 \text{ psi} \times 67{,}8363 \text{ in}}{(2 \times 13.700 \text{ psi} \times 0.85) - (0.2 \times 176{,}3508 \text{ psi})} + 0.002 \text{ in/tahun} \times 10 \text{ tahun}$$

$$= 1.237 \text{ in}$$

$$= 31{,}42 \text{ mm}$$