LAMPIRAN C

SPESIFIKASI PERALATAN

A. Spesifikasi Alat Proses

1. Tangki Penyimpanan *Metanol*

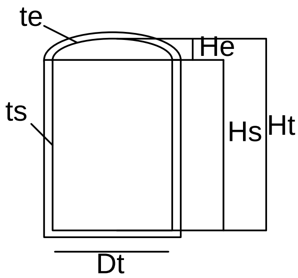
Fungsi : Untuk menyimpan bahan baku*metanol*

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 m^3

= 803070.183 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**

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

Maka,

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

- **Volume ellipsoidal, V_e**

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

- **Diameter tangki, D_t**

$$V_t = V_s + V_e$$

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

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

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

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

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

Tinggi tangki, H_t

- Tinggi silinder, H_s

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

- Tinggi *ellipsoidal*, H_e

  H_e=1/4D_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**

$t_e = \frac{0{,}885 P D_t}{SE - 0{,}6\ P} + C$ (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. Tangki Penyimpanan

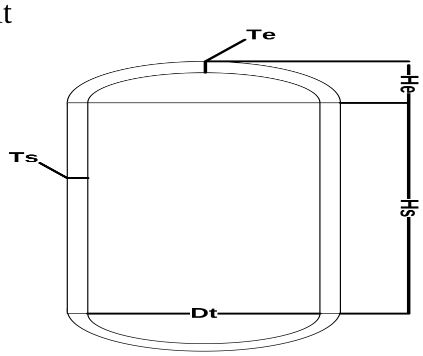
Fungsi : Untuk menyimpan bahan produkDimethyl ether

Tipe : Silinder vertikal dengan alas datar dan tutup elipsoidal

Bahan : *Low Alloy Steel* SA-387 grade 12C1.1

Jumlah : 1 unit

Gambar :



Data :

- Laju alir : 7839,697 kg/jam
- Densitas Umpan : 82 kg/m^3
- Temperatur : 30°C
- Tekanan : 22 atm

Kapasitas Tangki, V_t

Lama penyimpanan = 1 hari = 24 jam

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

$= \frac{7839{,}697 kg / jam}{82 kg / m^3}$ x 24 jam

= 2294,545 m^3

Faktor keamanan20 % (rule of thumb)

Maka,

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

$$= \frac{2294,545 m^3}{0,8}$$

$= 2868,182$ m^3

= 757693,330 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**

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

Maka,

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

- **Volume ellipsoidal, V_e**

$$V_e = \frac{\pi}{6}\, x\, D_t^2\, x\, H_e \qquad H_e = \frac{1}{4}\, D_t$$

Maka,

$$V_e = 0,1308\, x\, D_t^3$$

- **Diameter tangki, D_t**

$$V_t = V_s + 2V_e$$

$$V_t = \left(\frac{\pi}{4}\, x\, 1,5 D_t^3\right) + 2(0,1308\, x\, D_t^3)$$

$$V_t = 1,4391\, x\, D_t^3$$

$$Dt^3 = \frac{Vt}{1,4391}$$

$$Dt = \sqrt[3]{\frac{Vt}{1,4391}}$$

$$= \sqrt[3]{\frac{2868,182}{1,4391}} = \mathbf{12,553\ M}$$

Tinggi tangki, H_t

- Tinggi silinder, H_s

  H_s = 1,5 D_t = 18,829 m

- Tinggi *ellipsoidal*, H_e

  H_e= ¼ D_t = 6,276 m

- Tinggi tangki, H_t

  H_t = H_s + H_e

  = 18,829 m + 6,276 m = **25,105 m**

- **Tinggi Cairan, H_c**

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

  Hc = 15,063 m

- **Tekanan Cairan, P_c**

  $P_c = \rho . g . h_c$

  Pc =82$\frac{Kg}{M3}$ x 9,8 $\frac{M}{s^2}$ x 15,063 m

  Pc = 12117,216 $\frac{kg}{m.s^2}$

  = 0,118 atm

- **Tekanan Disain, P_d**

  Pd = Pop + Pc

  =22 atm + 0,118 atm

  = 22,118 atm

  =325,128 *psi*

- **Tebal dinding tangki, t_d**

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

- Tekanan desain, P : 325,128psi

- Jari-jari tangki, R : 247,101 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: 0,015 in/thn (Peter, Hal 542)
- Tahun digunakan : 10 tahun
- $t_d = \frac{325{,}128\ Psi\ x\ 247{,}101\ in}{(13700\ psi\ x\ 0{,}85)-(0.6\ x\ 325{,}128\ psi)} + 0{,}015 \frac{in}{tahun}\ x\ 10\ tahun$
- t_d = 7,167 in = 0,182 m

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

$t_e = \frac{PD_t}{2SE-0{,}2\ P} + C$ (Wallas, Tabel 18.4, Hal 537)

$$t_e = \frac{325{,}128\ psi\ x\ 494{,}202\ in}{(2\ x\ 13700\ psi\ x\ 0{,}85) - (0{,}2\ x\ 325{,}128\ psi)} + 0{,}15 \frac{in}{tahun} x\ 10\ tahun$$

= 7,068 in = 0,180 m

3. Pompa

Fungsi : Mengalirkan *metanol* menuju vaporizer

Tipe : *Centrifugal pump*

ambar:

Gambar C.5 Aliran pompa (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 : 22989,27462 kg/jam = 14,07837634lb/s
- Densitas , ρ : 796,1 kg/m^3 = 49,7 lb/ft^3

- Viskositas , μ : 1,429 cP = 3.456751 lb/ft.hr
- Tinggi pompa terhadap cairan masuk, Z_a : 0 m = 0 ft
- Tinggi pompa terhadap cairan keluar, Z_b : 2 m = 6.56 ft
- Panjang pipa hisap, L_s : 2 m = 6.56 ft
- Panjang pipa buang, L_d : 5 m = 16.4 ft
- 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

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

$$= \frac{14,078 \text{ lb/s}}{0,9}$$

$$= 15,64 \text{lb/s}$$

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

$$= \frac{15,64 \text{ lb/s}}{49,7 \text{ lb/ft}^3}$$

$$= 0,3147 \text{ ft}^3\text{/s} = 141,264 \text{ gal/min}$$

Diameter optimum, D_{opt}

Asumsi aliran turbulen

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

making design estimates:

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

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

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

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

Peter, Hal 496

$D_{opt} = 3{,}9\ x 0{,}3147^{0,45}\ x\ 49{,}7^{0,13}$

$= 3{,}85$ 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	4,500	0,37485	0,1143	4,500	0,37485	0,114
OD	3,826	0,3187	0,0972	3,826	0,3187	0.0971
a”	0,020943			ft^2		

Kecepatan aliran, V

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

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

$$= \frac{0{,}3147\ ft^3/s}{0{,}020943\ ft^2}$$

$= 15{,}028$ ft/s $= 54101{,}655$ ft/jam

$$\frac{V^2}{2gc} = \frac{(15{,}028\text{^}2)\ ft/s}{2\ x 32{,}17\ lbmft/s^2\ Ibf}$$

$= 3{,}5069$ ft-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 $\pi D_a n$,

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

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

$$N_{Re} = \frac{49{,}7\ lb/ft^3\ x\ 54101{,}655\ ft/jam\ x\ 0{,}3187\ ft}{3{,}4567\ lb/ft.jam}$$

$= 247909{,}62$ (>2100 aliran turbulen)

Rugi Gesek

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

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

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

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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:

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

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

Mc.Cabe

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

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

$$r_H = \frac{\pi D^2/4}{\pi D} = \frac{D}{4}$$

Mc.Cabe Hal 103

r_H $= \frac{0,3187 \text{ ft}}{4} = 0,07967$ ft

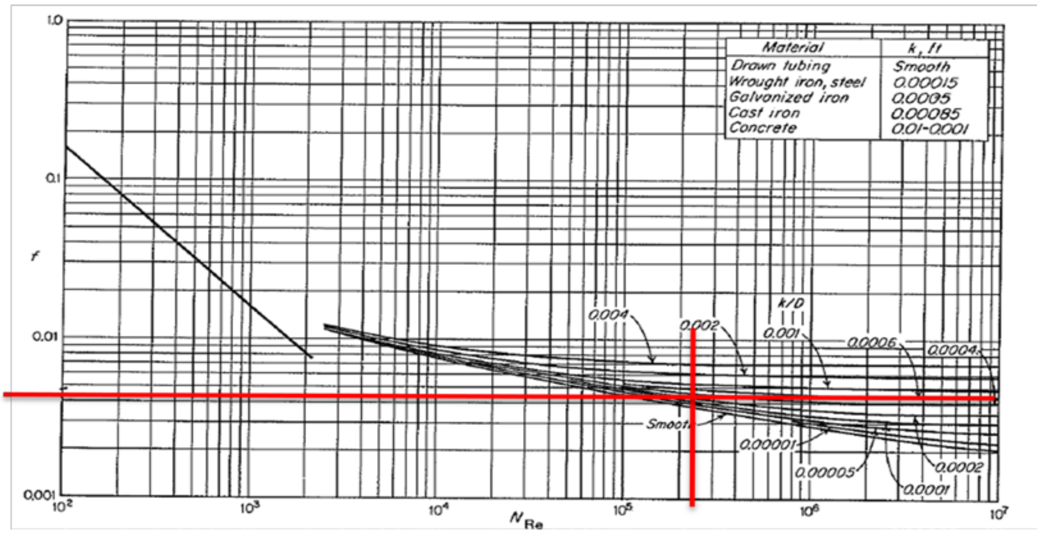
Nre = 247909,62

Material pipa yang digunakan adalah *wrought iron steel* :

k = 0,00015 ft Mc.Cabe Fig 5.9

k/D = 0,00047

f = 0,005 Mc.Cabe Fig. 5.9



$$h_{fsa} = \frac{0{,}005x\ 6{,}56\ ft\ x\ 3{,}5069\ ft - lb_f /lb}{0{,}07967\ ft}$$

= 1,44369 ft-lb_f/lb

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

$$h_{ffa} = Kf \frac{V^2}{2gc}$$ Mc.Cabe Pers 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):

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

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 = 0,9 x 1 = 0.9

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} = 1,1 x 3,5069 ft - lb_f /lb

= 3,85765 ft.lbf/lb

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

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

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

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

$$r_H = \frac{0{,}3187\ ft}{4} = 0{,}079676\ ft$$

Nre = 247909,6216

Material pipa yang digunakan adalah *wrought iron steel* :

k	= 0,00015 ft	Mc.Cabe Fig 5.9
k/D	= 0,00047	
f	= 0,005	Mc.Cabe Fig. 5.9

$$h_{fsb} = \frac{0{,}005 \times 16{,}4 \text{ ft} \times 3{,}5069 \text{ft - lb}_f/\text{lb}}{0{,}079676\,ft}$$

$= 3{,}6092$ ft.lb$_f$/lb

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

$$H_{ffb} = Kf\frac{V^2}{2gc} \quad \text{Mc.Cabe Pers 5.67}$$

Kf elbow	= 0,9 x 2 = 1,8	Mc.Cabe, Tabel 5.1
Kf Globe valve	= 10	
Kf Tee	= 1,8	
Kf	= 13,6	
H_{ffb}	= 13,6 x 3,506ft.lb$_f$/lb	
	= 47,69459ft.lb$_f$/lb	

Sehingga, rugi gesek total (hf_{total}) :

hf_{total} = hf suction + hf dischage

=51,66 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 = ρ_b

g/g_c = 1

α_a = α_b

Q = 141,264 gal/min

η = 57,5 % (Peters, Fig. 14.37)

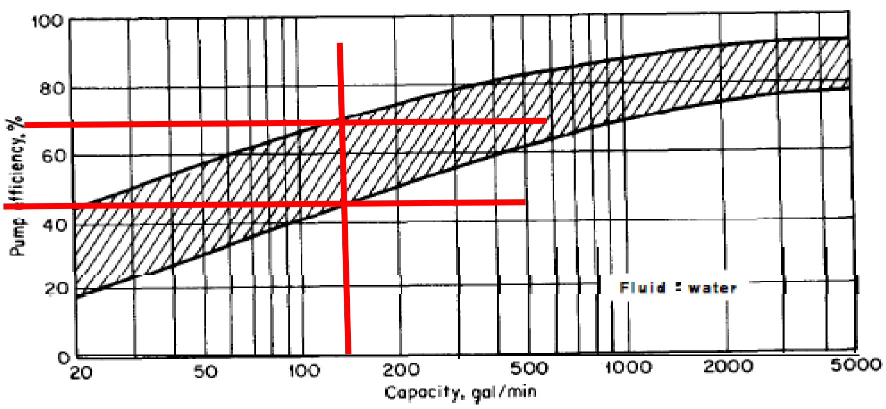


FIGURE 1437
Efficiencies of centrifugal pumps.

$$BHP = \frac{Wp \times m}{550}$$

$$= \frac{112{,}888 \text{ ft.lbf/lb} \times 14{,}07 \text{ lb/s}}{550}$$

$$= 2{,}889599 \text{ HP}$$

Daya motor (MHP)

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

η = 83 % (Peters, Fig 14.38)

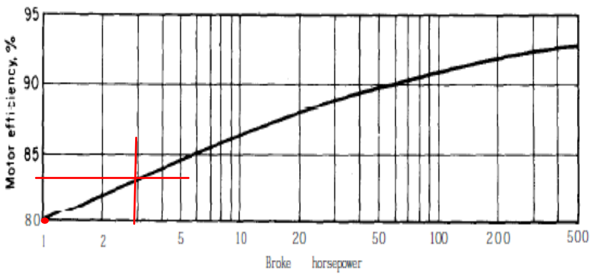


FIGURE 1438
Efficiencies of three-phase motors.

MPH $= \dfrac{2{,}889599 \text{ HP}}{83\%}$

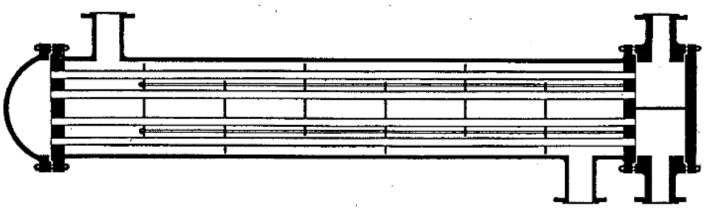
$= 3{,}481445$ HP

4. *Heate exchanger*

Fungsi : Memanaskan *metanol* yang di alirkan ke reaktor

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

Jumlah : 1



Gambar C.3 *Sheel and Tube Heat Exchanger*

1. Data dan Kondisi Operasi

A. Beban Panas (Q) = 8430127.23 kj/jam = 7991761 btu/jam

B. Fluida Panas

Laju Alir (W_t) = 1829.1kg/jam = 4032.51lb/jam

T_1 = 311 ºC = 586.2 ºF

T_2 = 303 ºC = 578.2 ºF

C. Fluida Dingin

Laju Alir (W_s) = 22989.27kg/jam = 50682.2lb/jam

t1 = 151 ºC = 303.8 ºF

t2 = 250 ºC = 482 ºF

2. Δt & LMTD

Fluida Panas (F)	Temperatur	Fluida Dingin (F)	Selisih	
579.2	Tinggi	482	97.2	ΔT2
579.2	Rendah	303.8	275.4	ΔT1

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

$$= \frac{(275.4 - 97.2)}{In\frac{275.4}{97.2}} = 171.1\ °F$$

Faktorkoreksi LMTD

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

= 0

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

= 0.647

Diasumsikan *Heat Exchanger Heater* (HE-101) merupakan HE dengan 1*Shell Pass* dan 2*Tube Pass*. Dari nilai R dan S, maka Faktor Koreksi dapat diperoleh dari Gambar 21 D.K. Qern adalah sebagai berikut:

F_T = 0.88

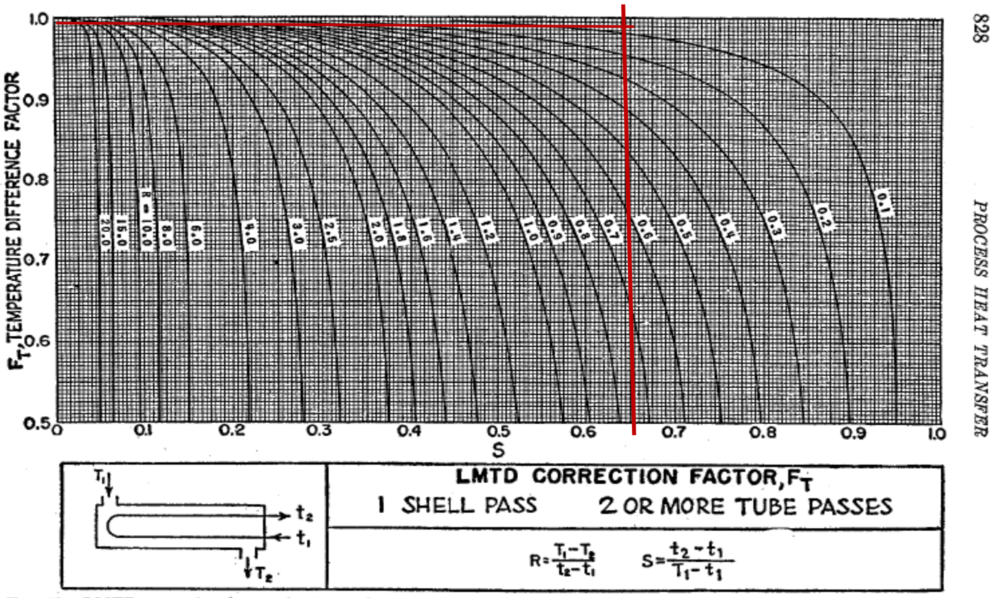


FIG. 18. LMTD correction factors for 1-2 exchangers. (*Standards of Tubular Exchanger Manufacturers Association, 2d ed., New York,* 1949.)

Sehingga :

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

= 171.1^{o}F x 0.99= 167.68^{o}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 = 30 Btu/jam.ft^2.F

Hot fluid	Cold fluid	Overall U_D
Water	Water	250–500§
Aqueous solutions	Aqueous solutions	250–500§
Light organics	Light organics	40–75
Medium organics	Medium organics	20–60
Heavy organics	Heavy organics	10–40
Heavy organics	Light organics	30–60
Light organics	Heavy organics	10–40

$$A = \frac{7991761\ \text{Btu/jam}}{30\text{Btu/jam.ft}^2\text{.F}\ x\ 167°\text{F}}$$

= 1588.647 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)	= 1.9 in	
Jenis tube	= 18 BWG	
Pitch (Pt)	= 0.9375 in Triangular Pitch	
Panjang tube (L)	= 12 ft	
a”	= 0.422 ft^2	(Tabel 10, DQ. Kern)

4. Menentukan Jumlah Tube

Jumlahtube :

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

$$= \frac{1588.647\ ft^2}{12\ ft x\ 0.422\ ft^2} = 313.7 \approx 314 \text{ buah}$$

Koreksi :

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

=314 x 12 x 0.42

= 1582.56 ft^2

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

$$= \frac{7991761 \;\; \text{Btu/jam}}{1582.56\text{ft}^2 x \; 167°\text{F}}$$

$= 30.23$ Btu/jam.ft^2.F

5. Spesifikasi *Shell and Tube*

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)	21	Diameter dalam (ID) in	0.75
Baffle space (B)=0,4xID	8 ½	Baffle Spacing	0.65
Passes (n)	3	BWG	18
		Pitch (Pt)	0.9375
		Passes (n)	3
		Panjang (ft)	12
		Jumlah Tube (N)	314

Shell, Fluida Dingin	**Tube, Fluida Panas**
6. Flow Area $a_s = \frac{IDxC' xB}{144 P_T}$ (D.Q Kern: pers. 7.1, hal 138) $= \frac{21 \text{in x } 0.2875 \text{ in x } 8.25 \text{in}}{144 \text{ x } 0.9375}$ $= 0.384664352$ ft^2	***6. Flow Area*** at' = 0.639 in2 (D.Q Kern, Table 10 hal 843) $a_t = \frac{N_t \; x \; at'}{144 n}$ (D.Q Kern: pers 7.48, hal 111) $= \frac{30 \; x \; 0.639 in^2}{144 x 3}$ $= 0.696687$ ft^2
7. Mass Velocity $G_s = \frac{Ws}{a_s}$ (D.Q Kern: pers 7.2, hal 138) $= \frac{50682.1548 \text{ lb/h}}{0.385 \text{ ft}^2}$ $= 131756.8279$ lb/hr ft^2	***7. Mass Velocity*** $Gt = \frac{Wt}{a_t}$ (D.Q Kern: pers 7.2, hal 138) $= \frac{4032.506197 \text{ lb/h}}{0.6967 \text{ ft}^2}$ $= 5788.1133$ lb/hr ft^2

8. Reynold Number $D_e = 1.0725 in$ = 0,08934 ft µ = 0.51Cp = 1.234 lb/ft.h (Fig. 9) $\mathrm{Re_s} = \frac{\mathrm{De\ x\ Gs}}{\mu}$ = $\frac{0.08934\ \mathrm{ft\ x}\ 131756.8279 \mathrm{lb/hr\ ft^2}}{1.234 lb/h.ft}$ = 23080.5287	**8.*Reynold Number*** µ = 0,052 Cp= 1.25788 lb/ft.h D = 0.75 in =0.062475 ft $\mathrm{Re_t} = \frac{\mathrm{D\ x\ Gt}}{\mu}$ $= \frac{0{,}062475\ \mathrm{ft\ x}\ 5788.1133\ \mathrm{lb/hr\ ft^2}}{1.25788 lb/h.ft}$ = 287.4776
9. Faktor Perpindahan Dingin (J_{Hs}) Dari gambar 28 D.Q.KERN maka didapatkan nilai Jh sebagai berikut: Jh = 30	**9.Faktor Perpindahan Panas(J_{Ht})** L = 12 ft D = 0.062475 ft L/D = 192.0768 Dengan memplotkan NRe dengan L/D ke gambar 24 D.Q.KERN maka didapatkan nilai Jh sebagai berikut: Jh = 2.2
10. Koefisien Perpindahan Pada T_c= 392.9 °F c = 0.51 Btu/lb°F (Perry Tabel 2-197) k = -2.906 Btu/ft.hr.°F (D.Q Kern, Tabel4) $\left(c.\frac{\mu}{k}\right)^{\frac{1}{3}} = \left(0.51 \mathrm{x} \frac{1.234 lb/ft.h}{-2.906 \mathrm{Btu/ft.hr.^0F}}\right)$ = -0.07216465	**10. Koefisien Perpindahan Panas** Pada Tc= 579.2 °F C = 0,52 Btu/lb°F(Perrys, Tabel 2-197) k = 0,089 Btu/ft.hr.°F (D.Q Kern, Tabel 5) $\left(c.\frac{\mu}{k}\right)^{\frac{1}{3}} = \left(0{,}52\ \mathrm{x} \frac{1.2578 lb/ft.h}{0.0089 \mathrm{Btu/ft.hr.^0F}}\right)^{1/3}$ = 10.224
11.*Inside Film Coefficient* (h_o) $\frac{h_o}{\phi_s} = jH.\frac{k}{D_e}.\left(\frac{C.\mu}{k}\right)^{1/3}$ (D.Q Kern: Pers 6.15 $= 30\ x\ \frac{\mathrm{-2.906Btu/ft.hr.oF}}{0{,}089\ ft} - 0.07$ = 70.42606485Btu/hr.ft2.°F	**11. *Inside Film Coefficient* (h_{io})** $\frac{h_i}{\phi_s} = jH.\frac{k}{D_e}.\left(\frac{C.\mu}{k}\right)^{1/3}$ $= 2.2x\ \frac{\mathrm{0{,}021325Btu/ft.hr.oF}}{0{,}062\ ft} 10.22$ = 7.6778Btu/hr.ft2.°F **KoreksiH_{io}kepermukaan OD** $h_{i0} = hi.\frac{ID}{OD}.$

	$= 7.6778 \text{Btu/hr.ft2.}^{\circ}\text{F}\ x\ \frac{0.65}{0.75}$ $= 251 \text{Btu/hr.ft2.}^{\circ}\text{F}$

12. Clean overall coefficient U_c

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

$$= \frac{251 x\ 70.43}{251 + 70.43}$$

$$= 54.9956 btu/hr.ft^{2.}{}^{\circ}F$$

13. Dirty Factor, R_d

$$Rd = \frac{U_C - U_D}{U_C\, x U_D} = \frac{54.99\ btu/hr.ft^2{}^{\circ}F - 30\ btu/hr.ft^2{}^{\circ}F}{54.99\ btu/hr.ft^2{}^{\circ}F\ x 30 btu/hr.ft^2{}^{\circ}F}$$

$$= 0.01515\ btu/hr.ft^2{}^{\circ}F$$

14. Pressure Drop, ΔP	
Re_s = 23080 f = 0,0016 ft²/in² (Kern: *fig*. 29, hal 839) s = 0.89(engineertoolbox.com) $(N+1) = N + \frac{L}{B}$ (D.Q Kern, pers. 7.43 hal 147) $= 314 + \frac{12}{8,25} = 315.41$ $Ø_s$= 1 lb/ft h $\Delta P_s = \frac{f\ x G_s{}^2 x D_s\ x\ N+1}{5,22\ x 10^{10}\ D_s x \phi_s}$ = 0,16783 psi	Re_t = 287.4776 f = 0,0019 ft²/in² (Kern: *fig*. 29, hal 836) s = 0.83 $Ø_s$= 1 lb/ft h $\Delta P_t = \frac{f\ x G_t{}^2 x\ L x\ n}{5,22\ x 10^{10}\ Dt\ x\ s\ x\ \phi_t}$ = 0,000564 psi • ΔP total Gt = 5788.1133lb/hr ft² $\Delta P_r = \frac{4\, x\, n}{s}\, x \frac{V^2}{2g}$ $\frac{V^2}{2g}$ = 0,045 (Kern: *fig*. 27, hal 837) $\Delta P_r = \frac{4x3/0.83}{0.045} = 0,6506 psi$ $\Delta P_t = \Delta P_t + \Delta P_r =$ 0.6525psi

5. Reaktor (RC-101)

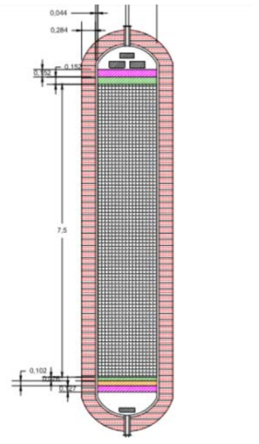
Fungsi :Tempat terjadinyareaksi metanol

Tipe : Vertical dengan alas dan tutup ellipsoidal

Bahan : Stainless Steel 316 Type SA- 240

Jumlah : 1 Unit

Produk



Feed

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**

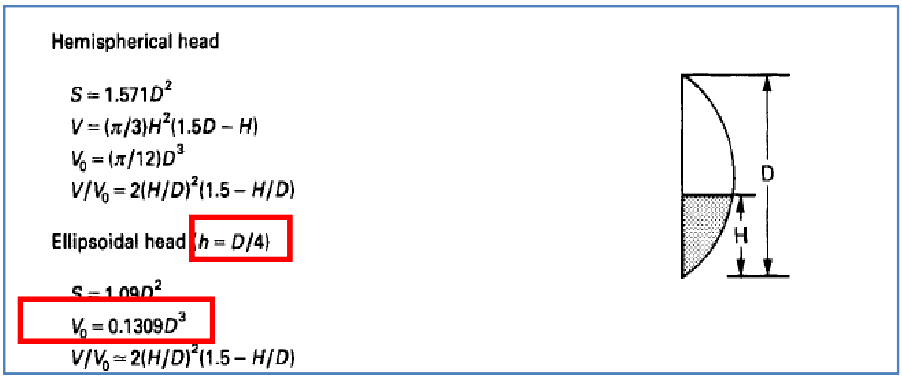
- **Volume silinder (Vs)**

$$Vs = \frac{\pi}{4} \times D_r^2 \times Hs$$
$$Vs = \frac{\pi}{4} \times D_r^2 \times 1{,}5Dr$$
$$Vs = \frac{\pi}{4} \times 1{,}5D_r^3$$

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 $(h = D/4)$

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

WallasTabel 18.5, hal650

- **Diameter reaktor, D_r**

$$Vr = Vs + 2Ve$$
$$Vr = (\frac{\pi}{4} \times 1{,}5D_r^3) + 2(0{,}1309D_r^3)$$
$$Vr = (1{,}4404D_r^3)$$
$$Dr = \sqrt[3]{Vr / 1{,}4404}$$

- $$Dr = \sqrt[3]{\frac{58{,}946858}{1{,}4404}}$$

- $$Dr = 3{,}446 \text{ m}$$

- **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	$\frac{PR}{SE-0.6P}$	$\frac{SEt}{R+0.6t}$	$\frac{P(R+0.6t)}{t}$	$t \le 0.25D$, $P \le 0.385SE$
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)	$\frac{PD}{2SE-0.2P}$	$\frac{2SEt}{D+0.2t}$	$\frac{P(D+0.2t)}{2t}$	$h/D=4$
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	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)**

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

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

$$= 1.237 \text{ in}$$

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

6. Flash drum

Fungsi : Untuk memisahkan fasa gas didalam liquid

Tipe : Silinder vertikal dengan alas tutup ellipsoidal

Bahan konstruksi : carbon steel (SA-285)

Komposisi umpan (F) yang masuk Flash drum yaitu :

T = 43,4°C = 316,4°C

P = 760 mmHg = 1 atm

Komponen	Masuk			Densitas	**Xi / p (kg/m3)**	Densitas Mix
	Kg/jam	lb/s	%			
DME	12607.32	7.7207	97.557	410	0.002379449	415.1063131
Metanol	252.5253	0.1546	1.954	792	2.46727E-05	
Air	63.13131	0.0387	0.488	997	4.8999E-06	
Total	12922.98				0.002409021	

Diketahui

Feed (F) : 12923 kg/jam

Laju alir gas : 3157 kg/jam

Laju alir liquid : 74 kg/jam

Densitas gas : 410,3187 kg/m^3 25,6162 lb/ft^3

Densitas liquid : 824,4619 kg/m^3 51,4712 lb/ft^3

Temperatur : 43,4 °C

Tekanan : 1 atm 101,325 Kpa

- Kecepatan maksimum gas (Vt)

$$V_t = 0{,}3\frac{ft}{s}\sqrt{\frac{\rho_l - \rho_g}{\rho_g}}$$

$$Vt = 0{,}3\frac{ft}{s}\sqrt{\frac{51{,}4712 - 25{,}6162}{25{,}6162}}$$

$$Vt = 0{,}3014\frac{ft}{s}$$

- Laju alir volumetrik fasa gas (Qv)

$$Q_v = \frac{m_{gas}}{\rho_{gas}}$$

$$Q_v = \frac{3157 kg / jam}{410{,}3187 kg / m^3}$$

$$Q_v = 7{,}6930\, ft / s$$

$$A_t = \frac{Q_v}{V_t}$$

$$A_t = \frac{0{,}00214 m^3/s}{0{,}09187 m/s}$$

$$A_t = 0{,}02326 m^2$$

- Diameter Vessel (D)

$$D = \pi r^2 = \left(\pi \frac{1}{2} D\right)^2 = \sqrt{\frac{4A}{\pi}}$$

$$D = \sqrt{\frac{4x0{,}02326}{3{,}14}}$$

$$D = 0{,}17214 m$$

$$D = 6{,}77716 in$$

- Laju alir volumetrik fasa liquid (Ql)

$$Q_l = \frac{m_{liquid}}{\rho_{liquid}}$$

$$Q_l = \frac{74 kg/jam}{824{,}4619 kg/m^3}$$

$$Q_l = 0{,}09 m^3/jam$$

$$Q_; = 000025 m^3/s$$

Waktu tinggal : 5 menit = 300 detik

$$V_l = \frac{Qlxt}{1440}$$

$$V_l = \frac{0.000025 m^3/s * 300 s}{1440}$$

$$V_l = 0{,}00000521 m^3$$

- Tinggi Vessel

H = 3 x D

H = 3*0,172140327

H=0,51642m

Diketahui :

Diameter (D)= 0,172140327m = 0,00437 in

Tekanan operasi (P) = 1 atm 101,325 kPa

Allowable stress(S) = 13700 psi 93197,3 kPa

Efisiensi (E) = 0,85

Corrosion Allowence (C) = 0,015 in/tahun

Corrosion Allowwence untuk 10 tahun = 0,15 in/tahun

Jari-jari(R) = 0,08607 m

- Volume vessel (Hv)

Vv= 0,25 x Π x D^2 x H

Vv= 0,25 x 3,14 x 017214^2 x 0,5164

Vv=0,012012649 m^3

- Volume ellipsoidal (He)

H e= ½ D

H e= 0,08607 m

V ellipsoidal = He x Dt^2

V ellipsoidal = 0,002550456 m^3

- Tebal vessel

$$t_v = \frac{PR}{(SE) - (0,6xP)} + C$$

Tv = 0,15 in 0,003810078 m

- Tebal ellipsoidal

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

t= 0,15 in 0,00381 m

7. Kompressor

   Fungsi : Menaikkan teakanan keluaran Flashdrum

   Jenis : Compressore Sentrifugas

   Jumlah : 1

   Data :

   Laju alir = 12922,98 Kg/jam = 28490 lb/jam

   Densitas Campuran = 2,16269 Kg/m^3

   Tekanan masuk (P1) = 1 atm = 101325 N/m^2

Tekanan keluar (P2) = 6,5 atm = 658612,5 N/m^2

a. Kapasitas Kompressor (Qs)

Qs = m/ρ

$$Qs = \frac{12922{,}98 kg/jam}{2{,}16269 kg/m^3}$$

$$Qs = 5975{,}4168 m^3/jam$$

Faktor keamanan 20%

Qs= 80% x 5975,4168 m^3/jam

Qs= 4780,33 m^3/jam

Qs= 1,3278

b. Rasio Kompressor (Rc)

dengan $C = \frac{mn}{n-1}\left[\left(\frac{p_d}{p_s}\right)^{\frac{n-1}{mn}} - 1\right]$

c_d = kecepatan udara masuk kompresor (m/s)

c_s = kecepatan udara ke luar kompresor (m/s)

C= 5,974877

c. Daya yang dibutuhkan (P)

Daya yang diperlukan kompresor tidak hanya untuk proses kompresi gas, tetapi juga untuk mengatasi kendala-kendala mekanis, gesekan-gesekan, kendala tahanan aerodinamik aliran udara pada katup dan saluran saluran pipa, kebocoran-kebocoran gas, proses pendinginan, dan lain-lain. Kendala-kendala tersebut akan mengurangi daya poros kompresor. Namun untuk menentukan seberapa besar pengaruh masing-masing kendala tersebut adalah sangat sulit. Secara teori perhitungan daya yang dibutuhkan untuk proses pemampatan kompresi bertingkat adalah sebagai berikut:

$$P_{ad} = p_s Q_s \frac{mn}{n-1}\left[\left(\frac{p_d}{p_s}\right)^{\frac{n-1}{mn}} - 1\right] \qquad C = \frac{mn}{n-1}\left[\left(\frac{p_d}{p_s}\right)^{\frac{n-1}{mn}} - 1\right]$$

$$P_{ad} = \frac{p_s Q_s C}{60000} \text{ kW}$$

dimana:
Pad = daya untuk proses kompresi adiabatis (kW)
m = jumlah tingkat kompresi
Qs = volume gas ke luar dari tingkat terakhir (m3/menit) (dikondisikan tekanan dan temperatur hisap)
ps = tekanan hisap tingkat pertama (N/m2)
pd = tekanan ke luar dari tingkat terakhir (N/m2)

n = 1,4 (udara) adiabatis
= 1 isoterma l

P= 13,3983 kW

P= 17,9674 Hp

Efisiensi kompressor = 80%

= 13,3983/ 80%

= 16,74788 kW

= 22,459 Hp

= 16747,88 Watt

8. PSA 1 (PSA-2031)

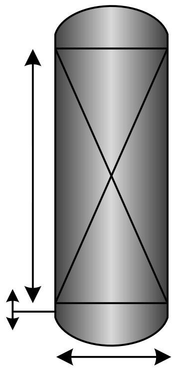
Fungsi : Untuk memisahkan gas DME dan Air dari impurities

Tipe : Vertikal Vessel

Bahan : *Carbon Steel* (SS515- Garde 55)

Jumlah : 2 unit

Gambar :



Data :

- Temperatur : 43,4 ºC = 110,12 F
- Tekanan : 8 atm = 8,104 bar
- Laju Alir Massa : 12922,98 kg/jam
- Bulk Density Zeolite : 0,65 Kg/L = 650 Kg/m^3
- Densitas Gas : 22,4053 Kg/m^3
- Waktu : 1 jam
- Jumlah Gas yang diserap : 239,899 Kg/jam
- Faktor Keamanan : 20%
- Kapasitas Zeolit : 3842,3 Ib/ton = 1742,54 kg
- π : 3,14
- Jumlah Zeolit : 2497,5 Ib= 1133,86 kg

Menentukan jumlah adsorber ziolit yang dibutuhkan

$$W_p = W_a /(1\text{-}F_a)$$ (Perry's 16-5)

Wp = 3121,87 Ib

Wp = 6876,36 Kg

Menentukan jumlah adsorber arang aktif yang dibutuhkan
Volume packing

$$Vp = \frac{Wp}{\rho zeolit}$$

Vp = 10,579 m^3

kapasitas kolom, Vk

$$V = \frac{laju\ \ alir\ \ massa\ \ x\ t}{Densitas}$$

V = 86,2 m^3

Vk = (1 x f)/V

Vk = 103,8

Volume total

VT = Vk + Vpziolit + Vparang aktif

VT= 190,34 m^3

Diameter

Volume Silinder

$$Vs = \frac{\pi\left(\frac{D}{2}\right)2 * L}{2}$$

$$Vs = \pi D^3$$

L =4D (trayball,p. 397 th 1981)

Diameter Adsorber

$$D = (\frac{Vt}{\pi})1/3$$

D = 3,87 m

Tebal dinding, t

Data :

- Tekanan : 8 atm
- Diameter : 3,87 m
- S (working stress allowable) :18700 (tabel 4, peter hal.538)
- E(Welding Joint Efisiensi) : 0,85 (tabel 4, peter hal.538)
- C (korosi yang diizinkan) : 0,0032 m (tabel 4, peter hal.538)

Recommended design equations for vessels under internal pressure	Limiting conditions
For cylindrical shells	
$t = \frac{Pr_i}{SE_J - 0.6P} + C_c$	$t \le r_i/2$ or $P \le 0.385SE_J$
$t = r_i\left(\frac{SE_J + P}{SE_J - P}\right)^{1/2} - r_i + C_c$	$t > r_i/2$ or $P > 0.385SE_J$
For spherical shells	
$t = \frac{Pr_i}{2SE_J - 0.2P} + C_c$	$t \le 0.356r_i$ or $P \le 0.665SE_J$
$t = r_i\left(\frac{2SE_J + 2P}{2SE_J - P}\right)^{1/3} - r_i + C_c$	$t > 0.356r_i$ or $P > 0.665SE_J$
For ellipsoidal head	
$t = \frac{PD_a}{2SE_J - 0.2P} + C_c$	0.5 (minor axis) = $0.25D_a$
For torispherical (spherically dished) head	
$t = \frac{0.885\,PL_a}{SE_J - 0.1P} + C_c$	r = knuckle radius = 6% of inside crown radius and is not less than $3t$
For hemispherical head	
Same as for spherical shells with $r_i = L_a$	

(Continued

Perrys hal 537 hal 4

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

$$t = \frac{30,9989}{31788,4} + 0,0032$$

t= 0,0042 m

t= 4,17 mm

Tinggi kolom

L = 3D

L= 7,7 m

Volme Tutup Ellipsoidal

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TABLE 4
Design equations and data for pressure vessels (Continued)

Properties of vessel heads (Include corrosion allowance in variables)	2: 1 Ellipsoidal	Hemi-spherical	Standard ASME torispherical
Capacity as volume in head, in?	$\frac{\pi D_a^3}{24}$	$\frac{2}{3}\pi L_a^3$	$0.9\left[\frac{2\pi L_a^2}{3}(IDD)\right]$
IDD = inside depth of dish, in.	$\frac{D_a}{4}$	L_a	$L_a - [(L_a - r)^2 - (L_a - t - r)^2]^{1/2}$
Approximate weight of dished portion of head, lbm	$\rho_m\left[\frac{\pi(nD_a + t)^2 t}{4}\right]$	$\rho_m[2\pi L_a^2 t]$	$\rho_m\left[\frac{\pi(OD + OD/24 + at)^2 t}{4}\right]$

Petters Hal 538 Tabel 4

$$Ve = \frac{\pi.\ D^3}{24}$$

$$Ve = \frac{182,68}{24}$$

$= 7{,}6\ m^3$

B. SPESIFIKASI PERALATAN UTILITAS

Dalam suatu pabrik, unit utilitas merupakan bagian yang penting agar proses utama dapat berlangsung sesuai dengan fungsinya. Unit utilitas disediakan berdasarkan kebutuhan operasional pabrik, yaitu :

a. Kebutuhan tenaga listrik
b. Kebutuhan *steam*
c. Kebutuhan air

1. Kebutuhan Listrik

a. Kebutuhan listrik pada peralatan proses

Tabel LC.4 Kebutuhan Listrik pada Peralatan Proses

Nama Alat	Daya (HP)
Pompa	62,3249724
Kompressor	114,738407
TOTAL	**177,063379**

Kebutuhan listrik pada peralatan proses

= (177,063379 Hp× 0,746 kW/Hp) = 132,0893 Kw

b. Kebutuhan listrik pada peralatan utilitas

Tabel LC.5 Kebutuhan Listrik pada Peralatan Utilitas

Nama Alat	Daya (HP)
Pompa	10,0028203
Tamgki pelarut	0,049313
Bak pencampur	0,003745
Bak flokulasi	0.1754
Cooling tower	5
Boiler	100,0000
TOTAL	**115,2313**

Kebutuhan listrik pada peralatan utilitas

= (115,2313Hp× 0,746 kW/Hp) = 85,96253 Kw

c. Kebutuhan energi listrik untuk peralatan instrumentasi diperkirakan 50 kwh.
Seperti : Alat – alat pengendali

d. Kebutuhan energi listrik untuk bengkel diperkirakan 100 kwh.
Seperti : Alat pemotong, mesin las, dll

e. Kebutuhan energi listrik untuk penerangan

- ✓ Luas area pabrik utama dan utilitas = 10.000 m^2
  Penerangan rata-rata Indoor = 10 watt/m^2

Total penerangan untuk pabrik = 7.500 m^2 x 10 watt/m^2

= 75.000 watt

= 75 kWh

Penerangan rata-rata Outdoor = 15 watt/m^2

Total penerangan untuk pabrik = 2.500 m^2 x 15watt/m^2

= 37.500 watt

= 37,5 kWh

- ✓ Luas perumahan = 20.000 m^2

>Indoor

Asumsi : 1 rumah karyawan memiliki daya listrik 900 watt

Total penerangan untuk pabrik = 900 watt x 25 unit rumah

= 22.500 watt

= 22,5 kWh

>Outdoor

Penerangan rata-rata = 10 watt/m^2

- ✓ Luas area kantor dan fasilitas lain = 3.000 m^2

Total penerangan untuk pabrik = 3.000 m^2 x 10 watt/m^2

= 30.000 watt

= 30 kWh

f. Kebutuhan energi listrik untuk peralatan kantor dan komunikasi

Seperti :

• 20 unit komputer (@ 300 watt)	= 6.000 watt
• 5 unit TV (@ 50 watt)	= 250 watt
• 10 unit AC (@ 300 watt)	= 3.000 watt
• 12 unit dispenser (@ 300 watt)	= 3.600 watt
• 5 unit kulkas (@ 110 watt)	= 550 watt
• 2 unit mesin photo kopi (@ 800 watt)	= 1.600 watt
• Dan lain-lain	= 800 watt
Jumlah	= 15.800 watt = 15,8 Kwh

Total kebutuhan listrik :

= (132,089 + 85,693+ 50 + 100 + 120 + 195 + 15,8)Kwh

= 698,582Kwh

Faktor keamanan 20% ……………………………………(*Peters, hal 37*)

Kebutuhan listrik sebenarnya = 1,2 x 698,582 Kwh

= 838,2984 Kwh

2. Kebutuhan Steam

a. *Steam*

Tabel LC.6 Kebutuhan *Steam* untuk Proses

Nama Alat	Massa (Kg/jam)
VP-101	13120,55
TOTAL	**13120,55**

3. Kebutuhan Air

a. Air pendingin

Tabel LC.7 Kebutuha Air Pendingin

Nama Alat	Massa (Kg/jam)
CD-101	11077,37424
TOTAL	**11077,3742**

b. Air sanitasi

Air sanitasi digunakan untuk:

a. Perumahan

Diperkirakan kebutuhan air perorangan ± 100 L/hari atau setara dengan 26,4 gallon/hari. Pabrikasam asetat ini memiliki 25 unit rumah yang disediakan untuk golongan tertentu. Asumsi 1 orang karyawan memiliki 4 orang anggota keluarga, sehingga jumlahnya menjadi 100 orang, maka kebutuhan air setiap jam:

$$= \frac{100\ liter}{hari} \times\ 100 \times \frac{0{,}997\ Kg}{liter} \times \frac{hari}{24\ jam} = 416{,}3954\ \text{kg/jam}$$

b. Perkantoran

Kebutuhan air perorangan ± 100 L/hari atau 26,4 gallon/hari, dengan jumlah karyawan 100 orang, kebutuhan air setiap jam adalah :

$$= 100 \times \frac{100\ liter}{hari} \times \frac{0{,}997\ Kg}{liter} \times \frac{hari}{24\ jam} = 416{,}40 \text{kg/jam}$$

c. Laboraturium diperkirakan sebanyak = 30 kg/jam

d. Poliklinik diperkirakan sebanyak = 30 kg/jam

e. Pemadam kebakaran diperkirakan sebanyak = 50 kg/jam

f. Masjid dan kantin diperkirakan sebanyak = 50 kg/jam +

Total kebutuhan air untuk sanitasi =992,7908kg/jam

1. Total Kebutuhan Air

Kebutuhan air per jam

- Air umpan *boiler* = 13120,554kg/jam
- Air *cooling tower* = 11077,37kg/jam
- Air sanitasi = 992,7908 kg/jam +

  Total = 25190,7148 kg/jam

Pada saat operasi kontinyu sejumlah air akan disirkulasikan dengan asumsi kehilangan air sebesar ± 10%

Air make up = sejumlah air *make up*

= 10%(umpan *boiler*+ *cooling tower*)

= 4839,5857 kg/jam

Jumlah air saat *start up* = total air + air *make up*

= 25190,7148 kg/jam+ 4839,5857 kg/jam

= 30030,31kg/jam

Jumlah air yang hilang = air sanitasi + air *make up*

= 992,7908 kg/jam+ 4839,5857 kg/jam

= 31023 kg/jam

Jumlah air yang dibutuhkan pada saat operasi kontinyu adalah

= 37227,71492 kg/jam

SPESIFIKASI PERALATAN UTILITAS

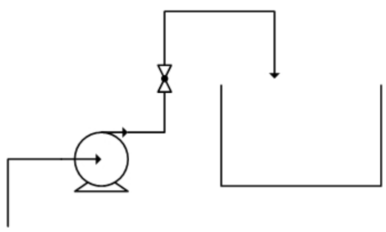
1. Pompa

Fungsi : Mengalirkan air dari sungai ke bak penampungan

Tipe : *Centriugal pump*

Bahan : *Carbon steel*

Gambar :



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 :33932,84kg/jam= 74821,907 lb/s
- Densitas , ρ : 1000 kg/m^3 = 62,4468989 lb/ft^3
- Viskositas , μ : 0,815 cP = 0,0005lb/ft s
- Tinggi pompa terhadap cairan masuk, Za : 3 m = 9,8425 ft
- Tinggi pompa terhadap cairan keluar, Zb : 4,2 m = 13,86 ft
- Panjang pompa hisap, Ls : 8 m = 26,25 ft
- Panjang pomp buang, Ld : 10 m = 32,8 ft
- Faktor keamanan 10% (Peter's, Tabel 6)

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TABLE 6
Factors in equipment scale-up and design

Type of equipment	Is pilot plant usually necessary?	Major variables for operational design (other than flow rate)	Major variables characterizing size or capacity	Maximum scale-up ratio based on indicated characterizing variable	Approximate recommended 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

(Peter's, Tabel 6)

Laju alir volumetrik, Q_v

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

$$= \frac{74821,90744 \text{ Ib/s}}{0,9}$$

= 23,0932lb/s

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

=0,3698 ft^3/s

= 165,9907 gal / min

Diameter optimum, D_{opt}

Asumsi aliran turbulen

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

making design estimates:

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

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

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

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

(Peter, Pers 14.15 Hal 496)

$D_{opt} = 3{,}9 \times (0{,}3698)^{0{,}45} \times (62{,}244)^{0{,}13}$

$= 3{,}9 \times 0{,}639 \times 1{,}7117$

$= 4{,}2665$ in

Dari Appendix 5 Mc. Cabe , hal 1087, diperoleh data sebagai berikut :

APPENDIX 5 DIMENSIONS, CAPACITIES, AND WEIGHTS OF STANDARD STEEL PIPE 1087

Nominal pipe size, in.	Outside diameter, in.	Schedule no.	Wall thickness, in.	Inside diameter, in.	Cross-sectional area of metal, in.^{2}	Inside sectional area, ft^2	Circumference, ft or surface, ft^2/ft of length: Outside	Circumference, ft or surface, ft^2/ft of length: Inside	Capacity at 1 ft/s velocity: U.S. gal/min	Capacity at 1 ft/s velocity: Water, lb/h	Pipe weight lb/ft
2	2.375	40	0.154	2.067	1.075	0.02330	0.622	0.541	10.45	5,225	3.65
		80	0.218	1.939	1.477	0.02050	0.622	0.508	9.20	4,600	5.02
2½	2.875	40	0.203	2,469	1.704	0.03322	0.753	0.647	14.92	7,460	5.79
		80	0.276	2.323	2.254	0.02942	0.753	0.608	13.20	6,600	7.66
3	3.500	40	0.216	3.068	2.228	0.05130	0.916	0.803	23.00	11,500	7.58
		80	0.300	2.900	3.016	0.04587	0.916	0.759	20.55	10,275	10.25
3½	4.000	40	0.226	3.548	2.680	0.06870	1.047	0.929	30.80	15,400	9.11
		80	0.318	3.364	3.678	0.06170	1.047	0.881	27.70	13,850	12.51
4	4.500	40	0.237	4.026	3.17	0.08840	1.178	1.054	39.6	19,800	10.79
		80	0.337	3.826	4.41	0.07986	1.178	1.002	35.8	17,900	14.98
5	5.563	40	0.258	5.047	4.30	0.1390	1.456	1.321	62.3	31,150	14.62
		80	0.375	4.813	6.11	0.1263	1.456	1.260	57.7	28,850	20.78
6	6.625	40	0.280	6.065	5.58	0.2006	1.734	1.588	90.0	45,000	18.97
		80	0.432	5.761	8.40	0.1810	1.734	1.508	81.1	40,550	28.57
8	8.625	40	0.322	7.981	8.396	0.3474	2.258	2.089	155.7	77,850	28.55
		80	0.500	7.625	12.76	0.3171	2.258	1.996	142.3	71,150	43.39
10	10.75	40	0.365	10.020	11.91	0.5475	2.814	2.620	246.0	123,000	40.48
		80	0.594	9.562	18.95	0.4987	2.814	2.503	223.4	111,700	64.40
12	12.75	40	0.406	11.938	15.74	0.7773	3.338	3.13	349.0	174,500	53.56
		80	0.688	11.374	26.07	0.7056	3.338	2.98	316.7	158,350	88.57

† Based on ANSI B36.10-1959 by permission of ASME.

(Appendix 5 Mc. Cabe, Hal 1087)

	Suction (a)				Discharge (b)			
IPS	6 in sch 40							
ID	4,026	in	0,3355	ft	4,026	in	0,3355	ft
OD	4,500	in	0,375	ft	4,500	in	0,375	ft
a"	3,17 ft^2							

Kecepatan aliran, V

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

Qv = 0,3698 ft^3/s

a'' = 3,17 ft^2

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

= 0,1167 ft/s

$$\frac{V^2}{2gc} = 0{,}0002 \text{ ft-lb}_f\text{/lb}$$

Bilangan Reynolds, N_{Re}

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

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 $\pi D_a n$,

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

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

(Mc. Cabe, Hal 249)

$$N_{Re} = \frac{62{,}4469 x 0{,}1167 x 0{,}3355}{0{,}0005}$$

= 4463

Rugi Gesek

Pipa hisap (*suction*)

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

$$h_{fs} = f \frac{\Delta L}{r_H} \frac{V^2}{2gc} \qquad \text{(Mc. Cabe, Pers 5.56)}$$

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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:

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

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

Mc.Cabe

(Mc Cabe, Pers 5.56)

$$r_H = \frac{ID}{4}$$ (Mc. Cabe, Hal 103)

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

$$r_H = \frac{\pi D^2/4}{\pi D} = \frac{D}{4}$$

(Mc. Cabe, Hal 103)

r_H $= \dfrac{0{,}3355\,ft}{4} = 0{,}0839$ft

Nre = 4462,8217

Material pipa yang digunakan adalah*wrought iron steel*:

k = 0,00015 ft (Mc.Cabe, Fig 5.9)

k/ID = 0,00015 ft/ 0,3355 ft

= 0,0004

Dari Fig 5.9 Mc. Cabe didapat f = 0,01

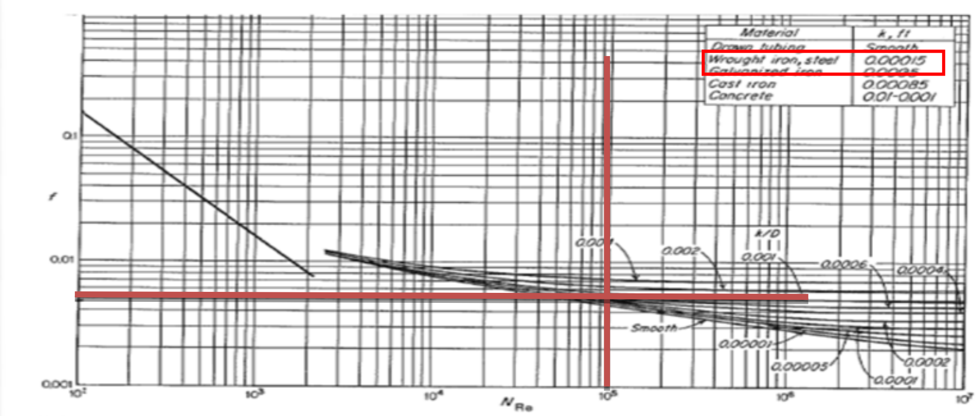


FIGURE 5.9
Friction-factor chart.

$$h_{fsa} = f\,\frac{\Delta L}{r_H}\,\frac{V^2}{2gc}$$

$$h_{fsa} = \frac{0{,}01 x 26{,}2467\, ft x 0{,}0002\, ft - ibf\,/\,ib}{0{,}0839\, ft}$$

$= 0{,}0007$ ft-lb_f/lb

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

$$h_{ff} = Kf\,\frac{V^2}{2gc}$$ (Mc.Cabe, Pers 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):

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

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

(Mc.Cabe, Pers 5.67)

Jumlah *gate valve* = 1

Kf *gate valve* = 10x 1 (Mc.Cabe, Tabel 5.1)

= 10

Jumlah *elbow* = 3

Kf *elbow* = 0,9x 3 (Mc.Cabe, Tabel 5.1)

= 2,7

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.

(Mc.Cabe, Tabel 5.1)

$h_{ff} \quad = Kf \dfrac{V^2}{2gc}$

h_{ff} = 12,7 x 0,0002 ft-lb_f/lb

= 0,0027 ft-lb_f/lb

h_f *suction* total = h_{fs} + h_{ff}

= 0,0008 ft-lb_f/lb + 0,0027ft-lb_f/lb

= 0,0035 ft-lb_f/lb

Pipa buang (*discharge*)

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

$h_{fs} \quad = f \dfrac{\Delta L}{r_H} \dfrac{V^2}{2gc}$ (Mc. Cabe, Pers 5.56)

$r_H \quad = \dfrac{ID}{4}$ (Mc. Cabe, Hal 103)

r_H = 0,0839 ft

Nre = 4462,8217

Material pipa yang digunakan adalah *wrought iron steel* :

k = 0,00015 ft (Mc.Cabe, Fig 5.9)

k/ID = 0,00015 ft/ 0,3355 ft

= 0,0004

f = 0,01 (Mc.Cabe, Fig 5.9)

$h_{fsb} \quad = f \dfrac{\Delta L}{r_H} \dfrac{V^2}{2gc}$

$h_{fsb} \quad = \dfrac{0.01x32{,}8084\, ftx0{,}0002\, ft - ibf\ /\ ib}{0{,}0839\, ft}$

= 0,0008ft-lb_f/lb

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

$h_{ff} = Kf \dfrac{V^2}{2gc}$ (Mc.Cabe, Pers 5.67)

Jumlah *globe valve* = 1

Kf *globe valve* = 10 x 1 (Mc.Cabe, Tabel 5.1)

= 10

Jumlah *elbow* = 3

Kf *elbow* = 0,9x 3 (Mc.Cabe, Tabel 5.1)

= 2,7

h_{ff} = 12,7 x 0,0002 ft-lb$_f$/lb

= 0,0027 ft-lb$_f$/lb

h_f *discharge* total = h_{fs} + h_{ff}

= 0.0007 + 0,0027ft-lb$_f$/lb

= 0,0037ft-lb$_f$/lb

Sehingga rugi gesek total (h_f) = h_f*suction* + h_f *discharge*

= 0,0008 ft-lb$_f$/lb + 0,0037 ft-lb$_f$/lb

=0,0044ft-lb$_f$/lb

Daya Pompa (BHP)

Daya pompa dapat dihitung dengan menggunakan Persamaan Bernoulli (Mc.Cabe, 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

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

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

(Mc.Cabe, Pers. 4.32)

Dimana

P_a = P_b

V_a = V_b

ρ_a = ρ_b

g/g_c = 1

α_a = α_b

Q = 165,9907144 gal/min

η = 61% (Peters, Fig. 14.37)

FIGURE 1436
Characteristic curves for a typical centrifugal pump showing effect of viscosity.

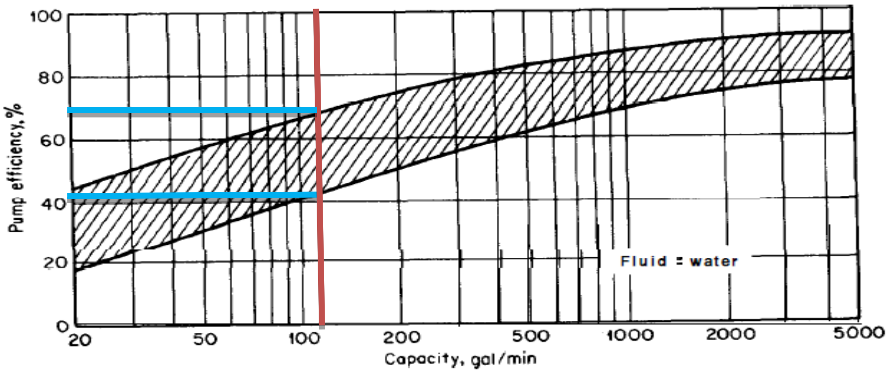


FIGURE 1437
Efficiencies of centrifugal pumps.

(Peters, Fig. 14.37)

Sehingga persamaan di atas dapat disederhanakan menjadi :

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

Wp $= \dfrac{13,8608 - (9,8425) + 0,0044}{61\%}$

= 6,5945 ft.lb_f/lb

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

$= \dfrac{6,5945x23,0932}{550}$

= 0,2769HP

Daya motor (MHP)

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

η = 74 % (Peters, Fig 14.38)

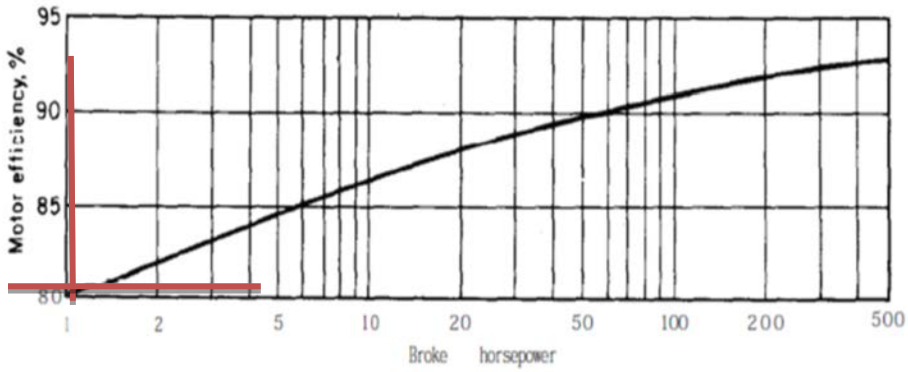


FIGURE 1438
Efficiencies of three-phase motors.

(Peters, Fig 14.38)

$$MPH = \frac{0,2769}{74\%}$$

= 0,3742 HP

Tabel LC- Daya Pompa pada Peralatan Proses

Kode Alat	Keterangan	Daya (HP)
P-1102	Pompa dari bak penampungan	0,1608
P-1103	Pompa dari tangki pelarutan kaporit	0,1533
P-1106	Pompa dari tangki pelarutan kapur tohor	0,1344
P-1107	Pompa dari tangki pelarutan alum	0,4027
P-1008	Pompa dari unit pengolahan *raw water*	1,1491
P-1009	Pompa dari *sand filter*	0,0756
P-1010	Pompa dari bak penampungan air bersih	3,1962
P-1011	Pompa dari *softener tank*	0,9496
P-1012	Pompa dari tangki air demin	0,3137
P-1013	Pompa kondensat masuk deaerator	1,2588
P-1014	Pompa dari *deaerator*	0,9496
P-1015	Pompa dari *plant* masuk *cooling tower*	0,9496
P-3114	Pompa dari *cooling tower*	35,4733

2. Bak Penampung Air Sungai

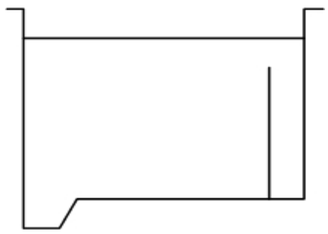
Fungsi : Menampung air sungai sebelum diolah menjadi air bersih

Jenis : Bak berbentuk empat persegi panjang

Jumlah : 1 buah

Konstruksi : Semen

Gambar :



Data :

- Laju alir massa, m : $33932{,}84 \frac{kg}{jam}$
- Densitas, ρ : 1000 kg/m^3
- Waktu tinggal : 24 jam

Laju alir volumetrik, Q

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

$$= \frac{33932{,}84 \frac{kg}{jam}}{1000\ kg/m^3} = 33{,}9328\ m^3/jam$$

Dimensi bak

$$V = 33{,}9328\ m^3/jam \times 24\ jam$$

$$= 814{,}388\ m^3 \approx 814 m^3$$

Direncanakan akan digunakan 2 unit bak penampungan sehingga kapasitas masing-masing bak adalah 407,194 m^3

Faktor keamanan 10%

Volume bak $= \frac{407{,}194 m^3}{0{,}9} = 452{,}438\ m^3$

Perbandingan dimensi bak penampung yaitu P : L : T = 3 : 2 : 1

Volume bak = panjang x lebar x tinggi

452,438 m^3 = 3T x 2T x T

$6T^3 = 452{,}438\ m^3$

T = 4,22476 m

Sehingga diperoleh dimensi bak :

Panjang = 3T = 12,6743m

Lebar = 2T = 8,44953 m

Tinggi = T = 4,22476 m

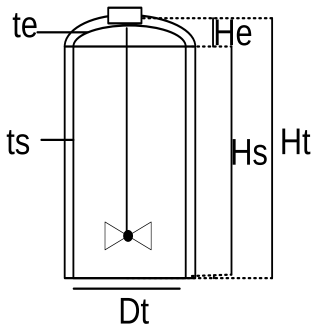
3. Tangki Pelarutan Alum

Fungsi : Tempat melarutkan alum ($Al_2(SO_4)_3$)

Jenis : Silinder vertikal dengan alas dan tutup *torispherical*

Konstruksi : *Carbon Steel*

Gambar :



Data :

- Laju alir volumetrik, Q = 33,93283784m^3/jam = 33932,84 ltr/jam
- Densitas campuran, ρ = 1620 kg/m^3=101,164 lb/ft^3
- Viskositas campuran, μ = 0,000452 lb/ft.s
- Faktor keamanan 20%
- Waktu tinggal =1 hari = 24jam
- Laju alir masa =33932,83784kg/jam

Kebutuhan alum

Kekeruhan air Sungai Noer Piter adalah sebesar 27 NTU

Berdasarkan jurnal teknik lingkungan vol 10 no 3 hal 265-270, untuk kekeruhan 22,5-30 NTU penggunaan alum yaitu sebesar 0,0000148 mg/ltr.

Kebutuhan alum = 0,0000148 kg/ltr air x 33932,84 ltr/jam

= 12,026 kg/jam = 26,517 kg/hari

Alum yang digunakan berupa larutan alum dengan konsentrasi 25% berat.

Berat larutan alum = $\frac{12,0258 kg/hari}{0,25}$ = 48,1032 kg/hari

Volume alum 25% = $\frac{48,1032 kg/hari}{1620 kg/m3}$ = 0,029693m^3/hari

Kapasitas tangki

Kebutuhan alum direncanakan untuk pemakaian selama 7 hari

Volume tangki = 0,0065358m^3/hari

Faktor keamanan 10%

Volume tangki = $\frac{0,0065358}{0,9}$

= 0,007262 m^3

Dimensi tangki,

- **Volume silinder, V_s**

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

Maka,

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

- **Volume *torispherical*, V_e**

$V_e = 0,0778\ D_t^3$ $\quad H_e = 1/4\ D_t$ (Wallas Tabel 18.5, hal 650)

- **Diameter Tangki, D_t**

$$V_r = V_s + V_e$$

$$V_r = \left(\frac{\pi}{4}\ x\ D_t^3\right) + (0,0778\ D_t^3)$$

$$= 0,8628\ D_t^3$$

$$D_t^3 = \frac{V_t}{0,8628}$$

$$= \frac{0,1653}{0,8628}$$

=0,1916

Dt =0,5768 m

= 22,7096 in

= 1,8920 ft

- **Tinggi *tangki*, H_r**

  Tinggi silinder,

  Hs = Dt = 0,5768 m

  Tinggi *Torispherical*,

  Hto $= \frac{1}{4} 0{,}5768 = 0{,}1630$

  Tinggi total (Ht)= Hs + Hto

  =0,5768+0,1630

  = 0,7398 m

- **Tinggi Cairan, H_c**

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

$= 0{,}6658$ m

- **Tekanan Cairan, P_c**

  $P_c = \rho . g . h$

  = 1620kg/m^{3}x10m/s^{2}x0,6658 m

  = 10786,5393 kg / ms^2

  = 1,5646 psi

  Tekanan Operasi = 14,7 psi

- **Tekanan Disain, P_d**

  $P_d = P_{operasi}\ x\ P_c$

  = 14,7 + 1,5646

  = 16,2645 psi

- **Tebal dinding tangki, t_d**

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

- Tekanan desain, P : 16,2645psi
- Jari-jari tangki, r : 11,3548 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 : 0,002 in/thn (Perry's Tabel 23-2)

- Tahun digunakan : 10 tahun

Maka,

t_d = 0,0359 in

t_d = 0,0009 m

- **Tebal dinding alas torispherical, t_e**

$$t_e = \frac{0{,}885\ PD_t}{(SE - 0.1P)} + C \qquad (Walas, Tabel\ 18.3)$$

- Tekanan desain, P : 11,4 psi
- Diameter tangki, D : 22,7096 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 : 0,002 in/thn (Perry's Tabel 23-2)
- Tahun digunakan : 10 tahun

$t_{e=}$ 0,0396 in

$t_{e=}$0,0010 m

Desain pengaduk

Untuk umpan dengan viskositas ≤ 4.000 cP, maka dipilih pengaduk jenis *propeller* berdaun 3 (Walas, hal 288)

Untuk mencegah *vortex*, maka pada *dissolved* tangki dipasang *buffle*

$$\frac{D_a}{D_t} = \frac{1}{3} \qquad \frac{H}{D_t} = 1 \qquad \frac{J}{D_t} = \frac{1}{12}$$

$$\frac{E}{D_t} = \frac{1}{3} \qquad \frac{W}{D_a} = \frac{1}{5} \qquad \frac{L}{D_a} = \frac{1}{4}$$

(Mc. Cabe, hal 264)

- **Diameter pengaduk, d**

$$D_a = {D_t}/{3}$$

$$\frac{0{,}5768}{3} \text{m} = 0{,}19 \text{ m} = 0{,}6307$$

- **Panjang daun pengaduk, L**

$L = {}^{D_a}/_4$

=0,1923/4

=0,05 m = 0,1261 ft

- **Lebar daun pengaduk, W**

$W = {}^{D_a}/_5$

= 0,1923/5

=0,04 m = 0,1261 ft

- **Tinggi pengaduk dari dasar tangki, E**

E = Dt/3

= 0,5768/3

=0,19 m = 0,6307 ft

- **Lebar *baffle*, J**

$J = {}^{D_t}/_{12}$

= 0,5768/12

=0,05 m = 0,1557

- **Kecepatan putar pengaduk, N**

$$\frac{N \times d}{\left(\frac{\sigma\ g_c}{\rho}\right)^{0.25}} = 1{,}22 + 1{,}25\left(\frac{Dt}{Da}\right)$$ (Robert E-Trybal, pers 6.18, hal 171)

$\sigma = 5{,}35\ \times 10^{-6}\ lb/ft$

$g_c = \ 32.17\ ft/dt^2$

Maka,

$$N = \frac{\left(1{,}22 + 1{,}25\left(\frac{D_t}{Da}\right) x\ \left(\frac{\sigma\, g_c}{\rho}\right)^{0{,}25}\right)}{Da}$$

= 2,1493 rps

- **Daya pengadukan, P**

$$N_{Re} = \frac{\rho \times N \times Da^2}{\mu}$$

$$= \frac{101{,}1366x2{,}1493x0{,}398}{0{,}0007}$$ (MC. Cabe Per 19.17, hal 270)

= 128653

Karena N_{Re}> 10000, maka

$$P = \frac{K_T N^3 Da^5 \rho}{g_c}$$ (Mc Cabe, Pers 9.24, hal 274)

$K_T = 0{,}32$ (Mc Cabe, Tabel 9.23, hal 275)

$$p = \frac{0{,}32x(2{,}1493rps)^3 x(0{,}18)^5 x101{,}1366}{32{,}17} x \frac{1hp}{550\, ftibf / s}$$

=0, 03945

$Efisiensi\ motor = 80\ \%$

$$\text{Daya motor} = \frac{0{,}03945}{0{,}8}$$

= 0,049313 HP

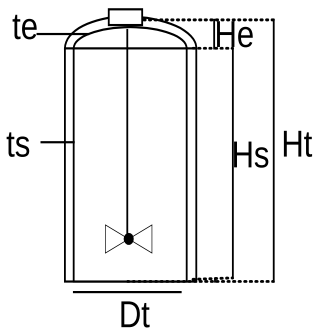
4. Tangki Pelarutan Kapur Tohor

Fungsi : Tempat melarutkan kapur tohor ($Ca(OH)_2$)

Jenis : Silinder vertikal dengan alas datar dan tutup *torispherical*

Konstruksi : *Carbon Steel*

Gambar :



Data :

- Laju alir volumetrik, Q = 33932,8 m^3/jam
- Densitas campuran, ρ = 73,7149 lb/ft^3 = 1182,56 kg/m^3
- Viskositas campuran, μ = 0,0005 lb/ft.s

Kebutuhan kapur tohor

Berdasarkan jurnal teknologi mineral vol 5 no 1, 2007, maka penggunaan kapur tohor yaitu sebesar1,88x10^{-5} kg/ltr air

Kebutuhan kapur tohor = 1,88x10^{-5} kg/ltr air x 33932kg/jam

= 0,63941 kg/jam

= 15,34584 kg/hari

Kapur tohor yang digunakan berupa larutan kapur tohor dengan konsentrasi 40% berat.

Berat larutan kapur tohor = $\frac{15{,}34584 kg/hari}{0{,}4}$ = 38,3646kg/hari

Volume kapur tohor 40% = $\frac{38{,}3646 kg/hari}{1117{,}187 kg/m^3}$ = 0,03434 m^3/hari

Kapasitas tangki

Kebutuhan kapur tohor direncanakan untuk pemakaian selama 7 hari

$$\text{Volume tangki} = \frac{0{,}042925 \frac{kg}{hari} x7}{1117187 kg/m^3}$$

= 0,0085 m^3

Faktor keamanan 10%

$$\text{Volume tangki} = \frac{0{,}00085 m^3}{0{,}9}$$

= 0,000944 m^3

Dimensi tangki

- Diameter Tangki = 2,723ft
- Tinggi Silinder = 0,906 ft
- Tinggi *torispherical* = 0,0756 m
- Tebal silinder = 0,0007 m

- Tebal tutup = 0,0009 m

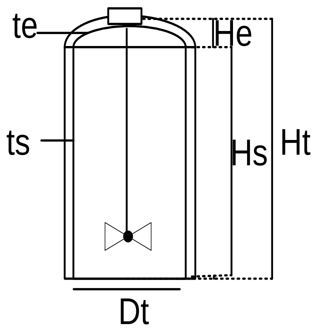
5. Tangki Pelarutan Kaporit

Fungsi : Tempat melarutkan kaporit ($Ca(OCl)_2$)

Jenis : Silinder vertikal dengan alas datar dan tutup *torispherical*

Konstruksi : *Carbon Steel*

Gambar :



Data :

- Laju alir volumetrik, Q = 33,932,8 m^3/jam
- Densitas campuran, ρ = 73,7149 lb/ft^3
- Viskositas campuran, μ = 0,0005 lb/ft.dtk
- Faktor keamanan 20%

Kebutuhan kaporit

Jumlah bakteri coliform 2266 MPN

Berdasarkan penelitian, untuk jumlah bakteri coliform 2266 MPN maka digunakan kaporit sebanyak 155 mg/liter

Untuk jumlah bakteri 3500MPN digunakan kaporit sebanyak 239,41 mg/liter.

Kebutuhan kaporit = $2,39x10^{-4}$ kg/ltr air x 33378,88804 ltr/jam

= 7,99 kg/jam

= 191,79 kg/hari

Kaporit yang digunakan berupa larutan kaporit dengan konsentrasi 40% berat.

Berat larutan kaporit = $\dfrac{191{,}79 kg/hari}{0{,}4}$ = 479,47 kg/hari

Volume kaporit 40% = $\dfrac{479{,}47 kg/hari}{1180 kg/m^3}$ = 0,41 m^3/hari

Kapasitas tangki

Kebutuhan kaporit direncanakan untuk pemakaian selama 1 hari

Volume tangki = $\dfrac{479{,}47 \dfrac{kg}{hari} x 1 hari}{1180 kg/m^3}$

= 0,4063 m^3

Dimensi tangki

- Diameter Tangki = 0,8060 m
- Tinggi Silinder = 0,8060 m
- Tinggi *torispherical* = 0,2015 m
- Tebal silinder = 0,0011 m
- Tebal tutup = 0,0015 m

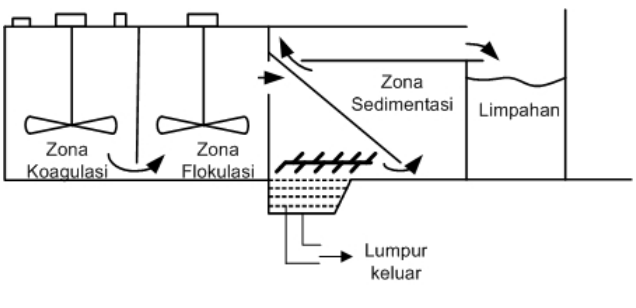
6. Unit Pengolahan *Raw Water*

Fungsi : Tempat pencampuran, pembentukan dan pengendapan flok-flok yang terkandung dalam air

Bentuk : Persegi panjang

Konstruksi : beton bertulang dengan ketebalan 15 cm

Gambar :



Data :

- Laju alir massa, m = 39.387,09 kg/jam
- Densitas, ρ = 997 kg/m^3 = 62,24271 lb/ft^3
- Viskositas, μ = 1 cP = 0,0007 lb/ft.dtk
- Waktu tinggal = 2 jam

Kapasitas bak

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

$$= \frac{39387,09 kg / jam}{997 kg / m^3} = 39,5056047 m^3/jam$$

$$V = Q \times t$$

= 39,5056047 m^3/jam x 2 jam

= 79,0012 m^3

Faktor keamanan 10%

$$V = \frac{79,00112 m^3}{0,9}$$

= 87,79023266 m^3

Dimensi bak

Perbandingan dimensi bak penampung yaitu P : L : T = 3 : 2 : 1

Volume bak = panjang x lebar x tinggi

71,3442 m^3 = 3T x 2T x1T

$6T^3$ = 87,79023266 m^3

T = 2,443673719 m

Sehingga diperoleh dimensi bak :

Panjang = 3T = 7,3310 m

Lebar = 2T = 4,8873 m

Tinggi = T = 2,4437 m

7. Bak Pencampur

Volume bak pencampur

Direncanakan panjang bak pencampur adalah 20% dari panjang bak unit pengolahan *raw water*.

Panjang bak pencampur = 20% x 7,3310 m = 1,4462 m

Sehingga ukuran bak pencampur adalah

Panjang = 1,4462 m

Lebar = 4,8873 m

Tinggi = 2,4437 m

Volume bak pencampur = P x L x T

= 17,5110 m^3

Perencanaan sistem pengaduk

Dimensi Pengaduk

- Diameter impeller = 1,63 m
- Panjang daun pengaduk = 0,41 m
- Lebar daun pengaduk = 0,33m
- Tinggi impeler dari dasar tangki = 1,63 m
- Lebar *baffle* = 0,41 m
- Kecapatan pengadukan = 0,2569 rps
- Daya motor = 0,0832 HP

Bak Pembentukan Flok

Volume bak pembentukan flok

Direncanakan panjang bak pembentukan flok adalah 20% dari panjang bak unit pengolahan *raw water*.

Panjang bak flokulasi = 20% x 7,3310 m = 1,4462 m

Sehingga ukuran bak pencampur adalah

Panjang = 1,4462 m

Lebar = 4,8873 m

Tinggi = 2,4437 m

Volume bak pencampur = P x L x T

= 17,5510 m^3

Perencanaan sistem pengaduk

Dimensi Pengaduk

- Diameter *impeller* = 1,63 m
- Panjang daun pengaduk = 0,41 m
- Lebar daun pengaduk = 0,33 m
- Tinggi impeler dari dasar tangki = 1,63 m
- Lebar *baffle* = 0,41 m
- Kecapatan pengadukan = 0,2569 rps
- Daya motor = 0,1040 HP

Bak Sedimentasi

Volume bak sedimentasi

Direncanakan panjang bak sedimentasi adalah 30% dari panjang bak unit pengolahan *raw water*.

Panjang bak sedimentasi = 30% x7,3310 m = 2,1993 m

Sehingga ukuran bak sedimentasi adalah

Panjang = 2,1993 m

Lebar = 4,8873 m

Tinggi = 2,4437 m

Volume bak sedimentasi = P x L x T

= 927,4700 m^3

Bak Penampung Berpelampung (*Float Chamber*)

Direncanakan panjang bak penampung adalah 30% dari panjang bak unit pengolahan *raw water*.

Panjang bak penampung = 30% x 7,3110 m = 2,1993 m

Sehingga ukuran bak penampung adalah

Panjang = 2,1993 m

Lebar = 4,8873 m

Tinggi = 2,4437m

Volume bak sedimentasi = P x L x T

= 927,4700 m^3

8. Sand Filter

Fungsi : Menyaring sisa-sisa flok yang berasal dari bak penampung berpelampung (*float chamber*)

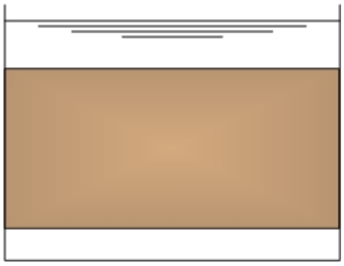
Bentuk : Persegi panjang

Konstruksi : beton bertulang

Isi : pasir silica, karbon dan batu-batu kecil

Jumlah : 1 unit

Gambar :



Data :

- Laju alir massa, m = 39.387,09 kg/jam
- Densitas, ρ = 997 kg/m^3 = 62,2427 lb/ft^3
- Waktu tinggal = 20 menit = 0,333 jam
- Visikositas = 1 cp=0,0007Ib/ft h

Kapasitas bak

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

$$= \frac{39387{,}09\,\frac{kg}{jam}}{997\,kg/m^3} = 39{,}5056047\ m^3/jam$$

V = 39,5056047m^3/jam x 0,333 jam= 13,1685 m^3

Faktor keamanan 10%

$$\text{Kapasitas bak} = \frac{13{,}685 m^3}{0{,}9} = 14{,}6317\ m^3$$

Kondisi filter

Porositas unggun, ε = 0,4

Air yang terisi dalam unggun 80% dari air masuk.

Volume ruang kosong = Volume yang terisi air

Volume unggun = V air yang mengisi unggun + V partikel

Air yang mengisi unggun = 80% x 14,6317m^3

= 11,7054m^3

Volume partikel = $\frac{11{,}7053 m^3}{0{,}4}$ = 29,2634m^3

Maka, volume unggun = (9,5125 + 23,7814) m^3 = 33,2939 m^3

Volume air yang tidak mengisi unggun= 20% x volume unggun

= 6,65879 m^3

Sehingga,

Volume unggun = V partikel + V air yang tidak mengisi unggun

= 40,9688m^3

Volume air yang tidak mengisi unggun= 20% x V unggun

= 8,19376 m^3

Volume bak = V unggun + V air yang tidak mengisi unggun

= 49,1625 m^3

Dimensi bak *sand filter*

Perbandingan dimensi bak *sand filter* yaitu P : L : T = 3 : 2 : 1

Volume bak = panjang x lebar x tinggi

49,1625 m^3 = 3T x 2T x T

6T^3 = 49,1625 m^3

T = 2,0146 m

Sehingga diperoleh dimensi bak :

Panjang = 3T = 6,0438 m

Lebar = 2T = 4,0292 m

Tinggi = T = 2,0146 m

9. Bak Penampung Air Bersih

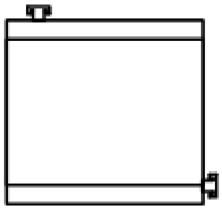
Fungsi : Menampung air bersih hasil penyaringan di *sand filter*

Jenis : Bak berbentuk empat persegi panjang

Jumlah : 2unit

Konstruksi : Beton bertulang dengan ketebalan 15 cm

Gambar :



Data :

- Laju alir massa, m : 39387,09 kg/jam
- Densitas, ρ : 997 kg/m^3
- Waktu tinggal : 24 jam
- Viskositas, μ : 1 cP = 0,0007 lb/ft.dt

Laju alir volumetrik, Q

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

$$= \frac{39387{,}09 \frac{kg}{jam}}{997 \frac{kg}{m^3}} = 39{,}5056 \text{ m}^3/\text{jam}$$

Dimensi bak

$V = 39{,}5056 \text{ m}^3/\text{jam} \times 24 \text{ jam}$

$= 948{,}134513 \text{ m}^3$

Direncanakan akan digunakan 2 unit bak penampungan sehingga kapasitas masing-masing bak adalah 474,0673 m^3

Faktor keamanan 10%

$$\text{Volume bak} = \frac{474{,}0673 m^3}{0{,}9} = 526{,}7414 \text{ m}^3$$

Perbandingan dimensi bak penampung yaitu P : L : T = 3 : 2 : 1

Volume bak = panjang x lebar x tinggi

526,7414 m^3 = 3T x 2T x T

$6T^3$ = 526,7414 m^3

T = 4,4378 m

Sehingga diperoleh dimensi bak :

Panjang = 3T = 13,3134 m

Lebar = 2T = 8,8756m

Tinggi = T = 4,4378 m

10. *Deminerilasasi*(*Kation + Anion Exchanger*)

Fungsi : Tempat pertukaran kation dan anion dalam air dengan H^+ dan OH^- dari resin

Jenis : Silinder vertikal dengan tutup dan alas *dished*

Jumlah : 1 unit

Konstruksi : *Carbon steel*

Gambar :

Data :

- Laju alir massa, m : 37.704,6504 kg/jam
- Densitas, ρ : 997 kg/m^3

Laju alir volumetrik, Q

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

$$= \frac{37.704,6504 \frac{kg}{jam}}{997 \frac{m^3}{jam}} = 37,8181 \text{ m}^3/\text{jam}$$

Faktor keamanan 10%

Maka,

$$Q = \frac{37,8181 m^3 / jam}{0,9}$$

$= 42,0201 \text{ m}^3/\text{jam}$

$= 1.483,7303 \text{ ft}^3/\text{jam}$

= 185,0090 galon/menit (GPM)

Berdasarkan data kapasitas yang diperoleh, maka dipilih alat *softener tank* tipe MHC-1200-3 dengan spesifikasi sebagai berikut (Marlo-inc.com, 2017)

Laju alir	: 55-190 GPM
Panjang	: 120 in
Lebar	: 64 in
Tinggi	: 98 in

11. Tangki Air Demin

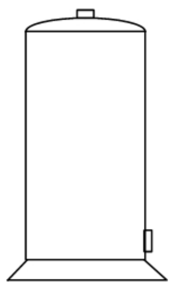
Fungsi : Tempat penyimpanan air bersih bebas mineral

Jenis : Silinder vertikal dengan alas datar dan tutup *torispherical*

Jumlah : 1 unit

Konstruksi : *Stainless steel*

Gambar :



Data :

- Laju alir massa, m : 37.704,65 kg/jam
- Densitas, ρ : 997 kg/m^3 = 62,2427 lb/ft^3

- Waktu tinggal : 15 menit = 0,25 jam
- Visikositas : 1 cp = 0,0007 Ib / ft h

Kapasitas tangki

$$V = \frac{m \times t}{\rho}$$

$$= \frac{37704{,}65 \frac{kg}{jam} x 0{,}25\, jam}{997 kg / m^3} = 9{,}4545 m^3$$

Faktor keamanan 10%

Maka,

$$V = \frac{9{,}4545 m^3}{0{,}9} = 10{,}5050\ m^3$$

Dimensi tangki

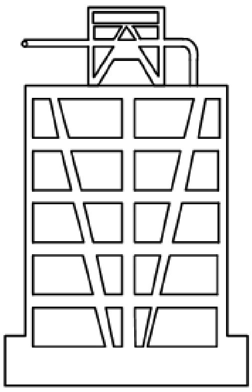
- Diameter Tangki = 2,2986 m
- Tinggi Silinder = 2,2986 m
- Tinggi *torispherical* = 0,5747 m
- Tebal silinder = 0,000512 m
- Tebal tutup = 0,000515 m

12. *Cooling Tower*

Fungsi : Mendinginkan air sirkulasi yang telah dipakai untuk pendinginan

Jenis : *Induced draft cooling tower*

Gambar :



Data :

- Laju alir massa, m : 369028,97kg/jam = 813561,3 lb/jam

- Densitas, ρ : 997 kg/m^3
- Temperatur masuk : 45°C = 113°F
- Temperatur keluar : 25°C = 77°F
- h_{udara} = h_u : 36,5 Btu/lb udara kering
- h_{air} = h_a : 105 Btu/lb udara kering

Berdasarkan Fig. 12.2 dan Fig. 12.3 Perry's, diperoleh data sebagai berikut :

- Temperatur bola basah : 23,89°F
- Temperatur bola kering : 22,5°F
- T_{av} = 95°F

Laju alir volumetrik, Wc

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

$$= \frac{369028{,}97\ \frac{kg}{jam}}{997 kg/m^3} = 370{,}139386 m^3/jam$$

= 1.629,67437galon/menit

Cooling tower yang digunakan adalah tipe *induced draft cooling tower* dengan aliran *counter current*.

Cooling range = 113°F - 77°F = 36°F

Luas *tower*, A

Kandungan air, Ca = 1,25 $gall/menit.ft^2$ (Perry's, Fig 12-14)

$$\text{Luas menara} = \frac{Wc}{Ca}$$

$$= \frac{1629{,}6737 gal/menit}{1{,}25 gall/menit.ft^2} = 1.303{,}73949\ ft^2$$

Factor keamanan 10%

$$\text{Maka, } A = \frac{1303{,}73949}{0{,}9} = 1.448{,}59944\ ft^2$$

Daya yang dibutuhkan *fan*

Performa standar menara 100%

Maka, daya yang didapatkan = 0,042 HP/ft^2 (Perry's, Fig 12-15)

Sehingga,

P_{act} = 0,042 HP/ft^2 x 1.448,59944 ft^2

= 60,8411763 HP

Dimensi *tower*

$$Dt = \frac{A \times \sqrt{Z_t}}{C_t \times \sqrt{C_t}}$$ (Perry's, Pers 12-15)

Dengan, Dt = koefisien bahan menara

A = luas menara

Zt = tinggi menara

Ct = koefisien performa menara = 5 (Perry's, Hal 12-21)

Untuk menghitung Dt digunakan persamaan :

$$\frac{W_L}{Dt} = 90{,}85 \left(\frac{\Delta h}{\Delta T}\right) \sqrt{\Delta t + (0{,}3124\Delta h)}$$ (Perry's, Pers 12-16)

Dengan Δh = perubahan panas = $h_a - h_u$ = 68,5 Btu/lb

ΔT = perubahan temperatur melalui menara

= 36°F

W_L = beban air pada menara

= 369028,968 kg/jam = 813561,3lb/jam

Δt = T keluar – T bola kering

= 77°F-75°F

= 2°F

Maka,

Dt = 972,956581 ft

Direncanakan Zt = 1,5 D

$$Zt^{0,5} = \frac{Dt(Ct\sqrt{Ct})}{A}$$

$$(1{,}5\ D)^{0,5} = \frac{Dt(Ct\sqrt{Ct})}{A}$$

$$(1{,}5\ D)^{0,5} = \left(\frac{56{,}3997(5\sqrt{5})}{1.159{,}7947}\right) = 37{,}5931 \text{ ft}$$

D = 11,4613 m

Sehingga, tinggi menara = 1,5 x 11,4613 m = 17,192 m

13. Unit Pengolahan Air Umpan Boiler

Air umpan boilermerupakan air yang digunakan untuk menghasilkan *steam*. Kebutuhan air umpan *boiler 8017,5356* kg/jam(17670,64856Ib) . Jika kondensat yang dapat diregenerasi 8017,5356 kg/jam dan asumsi 90 % yang dapat disirkulasikan kembali, maka kondensat yang disirkulasikan adalah = 8017,5356 kg/jam x 90% = 7215,782082 kg/jam

Maka air *make-up* yang dibutuhkan oleh *boiler* adalah

= (8017,5356 – 7215,782082) kg/jam

= 801,7536 kg/jam

14. *Deaerator*

Fungsi : Menghilangkan gas terlarut dalam air umpan boiler

Bentuk : Silinder horizontal dengan tutup dan alas *ellipsoidal*

Konstruksi : *Carbon steel*

Jumlah : 1 unit

Gambar :

Data :

- Air umpan boiler : 37704,65kg/jam = 83101 lb/jam

Direncanakan akan didesain *duo-tank deaerator* yang mampu mengolah 83101 lb/jam air umpan *boiler*.

Berdasarkan kapasitas tersebut, diperoleh data sebagai berikut.

- Tipe : SM70 D
- Diameter : 66 in = 1,6764 m
- Panjang tangki : 22 ft = 6,7073 m

Table 1-7. General Information, Duo-Tank Deaerator (Spraymaster Only)

Model No.	Rating lb/hr	Gallons to Overflow 10 Minute Storage	Tank Size
SM7 D	7,000	230/160	36" x 9'0"
SM15 D	15,000	300	48' x 11'6"
SM30 D	30,000	600	54" x 15'0"
SM45 D	45,000	900	60" x 17'3"
SM70 D	70,000	1,400	66" x 22'8"
SM100 D	100,000	2,000	72" x 26'0"
SM140 D	140,000	2,800	84' x 25'0"
SM200 D	200,000	4,000	96' x 26'3"
SM280 D	280,000	5,600	108' x 28'4"

NOTES:
Duo-Tank Deaerators have a 10 minute storage capacity in each section.
200 and 280 Models use two internal sprays.

(CleaverBrooks “Operation, maintenance, And Parts Manual Deaerator and Surge Controls)

15. *Boiler*

Fungsi : Menghasilkan *steam*

Tipe : *Water-tube boiler*

Konstruksi : *Carbon steel*

Jumlah : 1 unit

Gambar :

Data-data :

- Jumlah *steam* dibutuhkan = 8017,5356 kg/jam
- Kondensat yang diregenerasi = 7215,78028 kg/jam
- Air *make-up*= 801,753565kg/jam
- Jumlah *steam* yang dihasilkan = 801,753565 kg/jam

Berdasarkan data jumlah *steam* yang dihasilkan, maka dipilih *boiler* tipe THW-I 28-NTE-20 dengan spesifikasi sebagai berikut.

- Daya operasi : 100 HP
- Efisiensi : 93%
- Temperatur *flue gas* : 175°C
- Tekanan operasi : 10 bar

- Panjang : 3,98 m
- Lebar : 1,85 m
- Tinggi : 2,53 m
- Ketebalan insulasi : 0,1 m