BAB IX. ANALISA EKONOMI

Analisa ekonomi diperlukan untuk menentukan jumlah modal yang dibutuhkan untuk mendirikan dan mengoperasikan pabrik serta tinjauan kelayakan suatu pabrik. Faktor – faktor yang perlu ditinjau dalam analisa ekonomi adalah :

1. Investasi yang dibutuhkan untuk pendirian suatu pabrik sampai beroperasi yang dikenal dengan istilah *Total Capital Investment.*
2. Biaya produksi (*Total Production Cost*).
3. Harga jual produk yang dihasilkan.
4. Tinjauan kelayakan dari investasi yang disebut *Profitability Measure of Investment*. Tinjauan kelayakan ini terdiri atas perhitungan laba kotor dan laba bersih, laju pengembalian modal (*Rate of Return*), waktu pengembalian modal (*Pay Out Time*) serta titik impas (*Break Event Point*).

9.1 *Total Capital Investment* (TCI)

Total Capital Investment (TCI) adalah sejumlah modal yang ditanamkan/diresikokan untuk mendirikan pabrik sampai pabrik siap beroperasi. *Total Capital Investment* terbagi 2, yaitu :

a. *Fixed Capital Investment* (FCI)

   Fixed Capital Investment atau investasi biaya tetap adalah modal yang dikeluarkan untuk pembelian dan pemasangan peralatan pabrik serta alat penunjang lainnya sehingga pabrik dapat beroperasi. Berdasarkan perhitungan Lampiran D didapatkan *Fixed Capital Investment* sebesar US$ 54.324.092,72 atau Rp 792.612.958.675,18.

b. *Working Capital Investment* (WCI)

   Working Capital Investment atau investasi biaya kerja adalah modal atau biaya yang dikeluarkan untuk mengoperasikan pabrik sampai menghasilkan produk perdana. Biaya ini dimaksudkan untuk membiayai *start up*, gaji karyawan, pembelian bahan baku, pajak dan kebutuhan lainnya. Berdasarkan perhitungan Lampiran D didapatkan *Working Capital Investment* sebesar US$ 9.586.604,60 atau Rp 139.872.875.060,33.

Dengan demikian, *Total Capital Investment* adalah US$ 63.910.672,32 atau Rp 932.485.833.735,50.

9.2 Biaya Produksi (*Total Production Cost*)

Total Production Cost adalah biaya yang diperkirakan untuk menjalankan pabrik. Biaya produksi terbagi 2, yaitu:

a. Manufacturing Cost

Manufacturing cost adalah biaya yang berhubungan dengan produksi yang terdiri dari *Direct Production Cost*, biaya tetap dan biaya *overhead.* Berdasarkan perhitungan Lampiran D, didapatkan harga *manufacturing cost* seperti berikut.

- *Direct Production Cost* = US$ 10.992.789,88
  = Rp 160.392.630.484,97
- *Fixed Charge* = US$ 6.844.835,68
  = Rp 99.869.232.793,07
- *Plant Overhead Cost* = US$ 3.232.462,16
  = Rp 47.163.077.549,66

b. General Expenses (GE)

General expenses adalah biaya yang diperlukan untuk keperluan administrasi, distribusi, penjualan produk, penelitian dan pembiayaan lainnya. Berdasarkan perhitungan Lampiran D, *general expenses* yang didapatkan adalah US$ 11.254.533,89 atau Rp 164.208.714.043,19.

9.3 Harga Jual (*Total Sales*)

Produk utama yang dihasilkan pada pabrik ini berupa sabun cair dengan aroma kayu manis. Pabrik menjual sabun cair dengan harga sebesar US$ 3,4269/liter. Total penjualan sabun cair dengan kapasitas 20.000 Ton/tahun adalah sebesar US$ 65.916.280,62 atau Rp 961.748.196.625,96.

9.4 Tinjauan Kelayakan Pabrik

Tinjauan kelayakan pabrik sabun cair beraroma kayu manis dari PFAD dengan kapasitas produksi 20.000 Ton/tahun ini dapat dilihat dari 4 bagian berikut ini.

9.4.1 Laba Kotor dan Laba Bersih

Laba adalah hasil yang diperoleh dari total penjualan dikurangi total biaya produksi. Laba kotor adalah laba sebelum dikeluarkan pajak, sedangkan laba bersih adalah laba yang diperoleh setelah dikeluarkan pajak. Berdasarkan perhitungan Lampiran D, diperoleh laba sebagai berikut.

- Laba kotor yang diperoleh adalah = US$ 33.591.659,00
  = Rp 490.117.421.129,37
- Laba bersih yang diperoleh adalah = US$ 29.392.701,63
  = Rp 428.852.743.488,20

9.4.2 Laju Pengembalian Modal (*Rate of Return*)

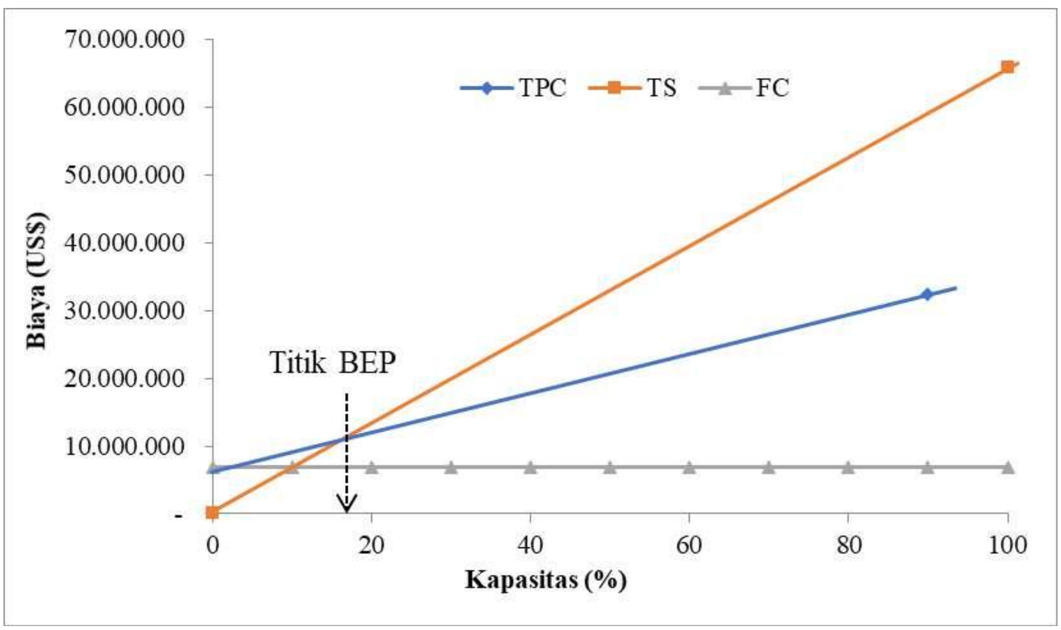
Rate of Return (ROR) merupakan perbandingan antara laba yang diperoleh tiap tahun terhadap modal yang ditanamkan. Berdasarkan perhitungan Lampiran D didapatkan nilai ROR sebesar 46%. Hal ini menandakan bahwa pabrik sabun cair beraroma kayu manis dari PFAD dengan kapasitas produksi 20.000 Ton/tahun layak didirikan.

9.4.3 Waktu Pengembalian Modal (*Pay Out Time*)

Pay Out Time (POT) merupakan lamanya waktu yang diperlukan untuk mengembalikan modal yang dipinjam. Berdasarkan perhitugan Lampiran D, POT yang didapatkan adalah 2 tahun 6 bulan 15 hari.

9.4.4 Titik Impas (*Break Event Point*)

Break Event Point (BEP) atau yang lebih dikenal dengan sebutan titik impas merupakan suatu kondisi dimana hasil penjualan produk sama dengan biaya produksi. Berdasarkan perhitungan Lampiran D didapatkan BEP sebesar 17%. Hal ini menunjukkan bahwa pada 17% dari kapasitas produksi yang terjual di pasaran pabrik sudah bisa menutupi biaya produksi atau pabrik dinyatakan baru balik modal. Kurva BEP ini dapat dilihat pada Gambar 9.1.



Gambar 9.1 Grafik *Break Event Point* (BEP)

BAB X. TUGAS KHUSUS

10.1 Pendahuluan

Perancangan alat proses pabrik sabun cair terdiri dari rancangan alat transportasi cair atau padat, alat perpindahan panas, reactor, rancangan alat pemisah dan pengadukan mixing tank. Pada tugas khusus ini perancangan alat transportasinya adalah *continuous vertical conveyor*, perancangan alat perpindahan panasnya yaitu shell and tube untuk reactor yaitu CSTR dan alat pemisahnya yaitu *decanter centrifuge* untuk tangki pengadukan yaitu mixing tank *Continuos vertical conveyor* adalah alat transportasi padat, tipe yang digunakan yaitu *Apron conveyor with pan.* pada prarancangan ini alat transportasi padat yang akan mengangkut bahan adiktif padat dari storage ke mixing tank, Rancangan selanjutnya yaitu reboiler tipe *shell and tube* fungsi alat ini yaitu untuk memanaskan umpan kolom destilasi, Sumber panas dari reboiler yaitu menggunakan steam. alat selanjutnya yaitu *CSTR* fungsinya untuk mereaksikan hasil keluaran dari mixing tank dan *deodorizer* sehingga menjadi produk yang diinginkan sabun cair, alat selanjutnya yaitu *decanter centrifuge* fungsi nya untuk memisahkan produk sabun dari reaktor dengan *triolein* berdasarkan berat jenis, Alat yang terakhir yaitu mixing tank 2 yang berfungsi untuk pencampuran sabun dengan minyak kayu manis.

10.1 Ruang Lingkup Rancangan

Perancangan peralatan proses yang di gunakan dalam produksi sabun cair terdiri atas rancangan alat penampungan, alat transportasi, perancangan alat perpindahan panas, reactor,rancangan alat pemisah dan alat pengadukan. Alat transportasi padat berupa *Continuos vertical conveyor*, alat perpindahan panas meliputi rancangan reboiler tipe *shell and tube,* reactor *CSTR* reactor merupakan tempat terjadinya reaksi kimia atara keluaran hasil alat *deodorizer* dan tangka KOH kemudian membentuk produk berupa sabun cair, serta rancangan *decanter sentrifuge* sebagai alat pemisah. Racangan lengkap peralatan proses dapat di lihat pada sub bab rancangan.

10.3 Rancangan

10.3.1 *Continuos vertical conveyor* (CVC- 4182)

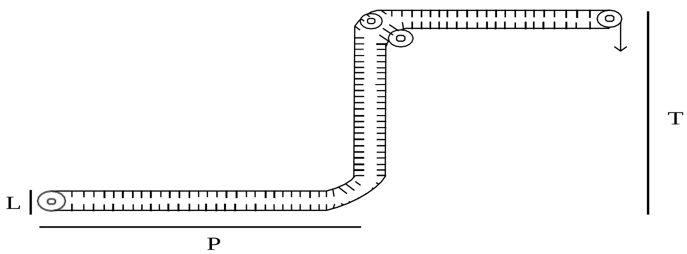
Fungsi : Mengangkut bahan adiktif Padat dari storage ke mixing tank

Tipe : *Apron conveyor with pan*

Bahan : *Carbon Stell (SA - 515). Grade 70 C -Si* *(Walas halaman 659)*

Jumlah : 1 Unit

Fasa : Padat



Gambar 10.1 *Continuos vertical conveyor* (CVC- 4182)

Tabel 10.1 komponen bahan adiktif

Komponen	M (kg/jam)	xi	ρ (kg/m^3)	V (m^3/jam)	U (CP)	%
$C_{13}H_9C_{13}N_2O$	21,5328	0,2085	1936	0,01112	23,9	20,85
$C_{16}H_{10}N2Na_2O_7S_2$	21,9722	0,2127	800	0,0274	28,9	21,27
$C_{10}H_{16}N_2O_6$	4,3505	0,0421	860	0,005	20	4,212
$C_{19}H_{38}N_2O_3$	19,2257	0,1861	1040	0,01848	14,9	18,617
H_2O	36,1881	0,3504	1000	0,0361	0,9	35,04
Total	103,2693	0,9998		0,0981		100%

Kondisi operasi

M = 103,2693 kg/jam

T = 30 ^{o}c

P = 1 atm

Faktor Keamanan = 10%

Laju Alir (T) = 0,1147437 ton/jam

Kecepatan (u) = 10 ft/min 3,0488 m/min *Perry's, Table 21 - 11*

Lebar Conveyor = 18 in 1,5 ft 0,4573 m *Perry's, Table 21 - 11*

Sesuai tinggi tangki

Panjang (L1) = 42,64 ft 13 m

Jarak horizontal (L2) = 32,8 ft 10 m

Jarak Vertical (L3) = 9,84 ft 2,9 m 3 dilebihkan sisa atas masuk ke tangki

$$HP = 0.001\left[\left(\frac{L_1}{30}+5\right)u+\left(\frac{L_2}{16}+2L_3\right)T\right]$$

Pers.5.26 walas selection design & chemical procces equipment

$$HP = 0.001[(L_1/30+5)u+(L_2/16+2L_3)T]. \quad (5.26)$$

where

u = ft/min,

T = tons/hr,

L_1 = total belt length (ft),

L_2 = length of loaded horizontal section (ft),

L_3 = length of loaded vertical section (ft).

Keterangan :

Laju Alir (T) = ton/jam

Kecepatan (U) = ft/min

Panjang (L1) = ft

Panjang Horizontal (L2) = ft

Panjang Vertikal (L3) = ft

Halama 81

Asumsi

b= 0,001

b = 1,42133

= 16,42133

c = 21,73

d = 1,1611

Daya = 0,01759

≈ 0,5 Hp

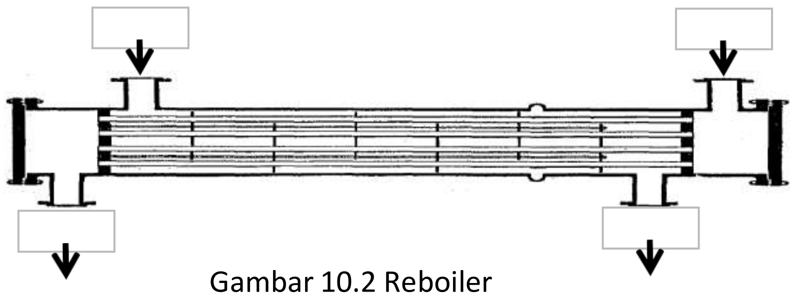
Interpolasi untuk lebar conveyor :

$$Y = Y_1 + \frac{(X - X_1)}{(X_2 - X_1)} x(Y_2 - Y_1)$$

Kapasitas = 2,3801 (lebar conveyor)

10.3.2 Reboiler (RB-1081)

Fungsi	=	Untuk memanaskan umpan kolom destilasi I
Tipe	=	*Shell and Tube Heat Exchanger*



Gambar 10.2 Reboiler

1. Data dan kondisi operasi :

a. Fluida Panas = *Steam*

Laju ali : 334,7113 kg/jam

= 737,905 lb/jam

Temperatur : T1 = 242 ^{o}c

= 467,6 ^{O}F

T2 = 242 ^{o}c

= 467,6^{O}F

b. Fluida dingin = *Top Product*

Laju alir : 188,4572 kg/jam

= 415,4727 lb/jam

Temperatur : t1 = 30 ^{o}c

= 86 ^{O}F

t2 =226 ^{o}c

= 226 ^{o}c

Beban panas yang dibutuhkan : 140313,2846 kkal/jam = 556763,1133 btu/jam

2. LMTD ***(Log Mean Temperature Difference)***

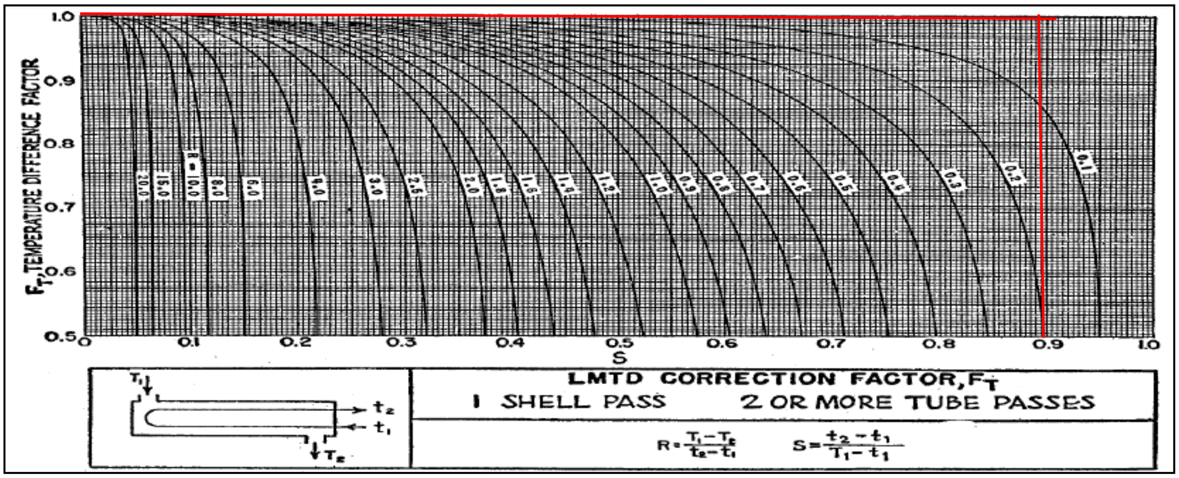
Tabel 10.2 Data fluida panas dan fluida dingin

Fluida Panas	Temperatur	Fluida Dingin	Selisih	Tav	tav
467,6	T tinggi	438,8	28,8	467,6	262,4
467,6	T rendah	86	381,6		
		352,8	-352,8		

LMTD = $\frac{(T_1 - t_2) - (T_2 - t_1)}{\ln (T_1 - t_2)/(T_2 - t_1)}$

= 136,5326371 ^{o}f

Fig 18 D.Q Kern hal 828



Faktor koreksi LMTD

R = $\frac{T_1 - T_2}{t_2 - t_1}$

R = 0

FT = 1 *Fig 18 D.Q Kern Hal 828*

Maka, Δt = FT x LMTD

= 136,5326371 ^{O}F

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

S = 0,924528

3. Luas area perpindahan panas, A

Berdasarkan Tabel 8 - DQ Kern Hal 840, diperoleh :

UD =20 Btu/jam.°F

Maka , $A = \frac{Q}{U_D \; x \; LMTD}$ DQ. Kern Pers 7.42 Hal 144

A = 203,8937815 ft^2

4. Spesifikasi Shell and Tube

Tabel 10 - Hal 843

OD (in)	A" (ft2)	BWG	L (ft)
1	0,2618	13	16

5. Menentukan Jumlah Tube

Jumlah tube : $\frac{A}{L \; x \; a''}$

Nt = 48,67594095 ≈ 49

Koreksi :

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

A = 203,893781

Ud = $\frac{Q}{A \; x \; \Delta t}$

Ud = 20

Berdasarkan table 9 untuk jumlah tube 57 di proleh s

Shell side		*Tube side*	
ID (in)	13,25	*Number*	56
Baffle space (in)	5	*Length*	16
Passes	1	*OD (in)*	1
		BWG	13
		pitch (in) – square	1,25
Clearance, C'	0,25	*Passes*	2

Diketahui bahwa baffle space 1/3 - 1/5 ID shell < B < ID shell (Peter, Hal 610)

Tabel 9 – Hal 842

TABLE 9. TUBE-SHEET LAYOUTS (TUBE COUNTS)
Square Pitch

¾ in. OD tubes on 1-in. square pitch						1 in. OD tubes on 1¼-in. square pitch					
Shell ID, in.	1-P	2-P	4-P	6-P	8-P	Shell ID, in.	1-P	2-P	4-P	6-P	8-P
8	32	26	20	20		8	21	16	14		
10	52	52	40	36		10	32	32	26	24	
12	81	76	68	68	60	12	48	45	40	38	36
13¼	97	90	82	76	70	13¼	61	56	52	48	44
15¼	137	124	116	108	108	15¼	81	76	68	68	64
17¼	177	166	158	150	142	17¼	112	112	96	90	82
19¼	224	220	204	192	188	19¼	138	132	128	122	116
21¼	277	270	246	240	234	21¼	177	166	158	152	148
23¼	341	324	308	302	292	23¼	213	208	192	184	184
25	413	394	370	356	346	25	260	252	238	226	222
27	481	460	432	420	408	27	300	288	278	268	260
29	553	526	480	468	456	29	341	326	300	294	286
31	657	640	600	580	560	31	406	398	380	368	358
33	749	718	688	676	648	33	465	460	432	420	414
35	845	824	780	766	748	35	522	518	488	484	472
37	934	914	886	866	838	37	596	574	562	544	532
39	1049	1024	982	968	948	39	665	644	624	612	600

Cold Fluid: tube side, Ethanol

6. Flow area per tube

α 'tube = 0,515 in^2 (Tabel 10 Hal 843)

α 'tube = $\frac{N_t \alpha'_t}{144\eta}$ (Pers 7.48 Hal 150)

α 'tube = 0,100138889 Ft^2

7. Mass velocity

Ga = $\frac{W}{a_t}$

Ga = 4148,96498 lb/jam Ft^2

8. NRe, bilangan Reynold

NRe = $\frac{D_t G_t}{\mu}$ (per 3.6 Hal 41)

pada tc 126.5 ºF, µ = 1,1 cp (*fig* 14 Hal 823)

= 2,66112 lb/ft.jam

ID = 0,8 in

= 0,0675 ft

NRe = 105,2995744

9. jH

L/D = 237,037037

jH = 1,5 (*Fig* 24 Hal 834)

10. TC

Tc = 262,4 °F

C = 0,95 Btu/lb.°F (*fig* 2 Hal 804)

K = 0,8 Btu/jam.ft² .°f/ft (Tabel 4 Halaman 801)

$$= \left(\frac{c\mu}{k}\right)^{1/3} = 1{,}66896457$$

11. Condensation of steam

$$hi = J_h \frac{k}{D}\left(\frac{c\mu}{k}\right)^{1/3} \Phi t$$ (per 6.15 Hal 111)

hi/φt = 26,07815924 Btu/jam.ft².°f

12. hio

$$\frac{h_{io}}{\varphi_t} = \frac{h_i}{\varphi_t} \; x \; \frac{ID}{OD}$$ (per 6.5 Hal 111)

= 21,12330899

karena viskositas rendah, maka asumsi

ϕs = 1

$$ho = \frac{h_a}{\varphi_s} \; x \; \varphi_s$$

=21,12330899

Tube O.D. in.	Pitch		d_e
3/4	1" square		0.95
1	1¼"	"	0.99
1¼	1 9/16"	"	1.23
1½	1 7/8"	"	1.48
3/4	15/16" Triangular		0.55
3/4	1"	"	0.73
1	1¼"	"	0.72
1¼	1 9/16"	"	0.91
1½	1 7/8"	"	1.08

13. Clean overall coefficient, Uc

$$UC = \frac{h_{io}\, h_o}{h_{io} + h_o}$$

UC = 20,829977 Btu/hr ft^2 ^{o}f

14. Design overall coefficient, Ud

Total surface, A = 234,5728 ft^2

$$U_D = \frac{Q}{A.\,\Delta_t}$$

UD = 17,38426463 Btu/jam.ft^2.^{o}f

≈ 20 Btu/jam. Ft^2.^{o}f

15. Dirt factor, Rd

$$R_D = \frac{U_C - U_D}{U_C\, x\, U_D}$$

Rd = 0,00951555

16. Summary

467,6	h outside 262,4
UC	20,82997696
UD	17,38426463
RD calculated	0,00951555
RD required	0,001

Tabel 12 Hal 845

Petroleum Fractions

Oils (industrial):	
Fuel oil	0.005
Clean recirculating oil	0.001
Machinery and transformer oils	0.001
Quenching oil	0.004
Vegetable oils	0.003
Gases, vapors (industrial):	
Coke-oven gas, manufactured gas	0.01
Diesel-engine exhaust gas	0.01
Organic vapors	0.0005
Steam (non-oil bearing)	0.0
Alcohol vapors	0.0
Steam, exhaust (oil bearing from reciprocating engines)	0.001
Refrigerating vapors (condens-	
Liquids (industrial):	
Organic	0.001
Refrigerating liquids, heating, cooling, or evaporating	0.001
Brine (cooling)	0.001
Atmospheric distillation units:	
Residual bottoms, less than 25°API	0.005
Distillate bottoms, 25°API or above	0.002
Atmospheric distillation units:	
Overhead untreated vapors	0.0013
Overhead treated vapors	0.003
Side-stream cuts	0.0013
Vacuum distillation units:	
Overhead vapors to oil:	

17. Pressure Drop : tube side

1. For NRe

NRe = 0,81

f = 0,002 *(Fig 29 Hal 839)*

$i \;\; s = 0{,}96$ *(Fig 6 Hal 809)*

2. ΔPt

ΔPt = $\frac{fG_t^2 Ln}{5.22x10^{10} D_{e's} \Phi_t} =$

ΔPs = 0,000325697 psi

3. Gt

Gt = 4148,96498

$\frac{V^2}{2g'}$

= 0,04 (fig 37 Hal 837)

$$\Delta P_T = \frac{4n}{s} x \frac{V^2}{2g'}$$

ΔPT = 0,333333333 psi

4. ΔPT

= $\Delta P_T = \Delta P_{t1} + \Delta P_{t2}$

ΔPT = 0,333659031 psi

* Perancangan Heater dengan tipe shell and tube , memenuhi syarat karena nilai ΔP < 10 Psi.

Hot Fluid: shell side, Steam

6. Flow area per shell

$$a_s = ID \; x \frac{C' \, x \, B}{144 \; Pt}$$ (per.7.1 Hal 138)

α ' shell = 0,092014 ft^2

7. Mass velocity

Gs = $\frac{W}{a_t}$

GS = 8019,491 lb/jam.ft^2

8. NRe, bilangan Reynold

NRe = $\frac{D_e G_s}{\mu}$ (per.3.6 Hal 41)

pada Tc 266 ºF, μ = 0,17 cp (fig 14 Hal 823)

= 0,411264 lb/ft.jam

$$de = \frac{4\ x\ \left(Pt^2 - \pi\ OD^2 / 4\right)}{\pi\ x\ OD}$$ (per 7.4 Hal 138)

de = 0,990446 in

De = 0,082537 ft

NRe = 1.609,443

9. jH

jH = 54 (*Fig* 28 Hal 834)

10. Tc

Tc = 467,6 ^{o}f

C = 1,1 Btu/lb.^{o}f (*fig* 2 Hal 804)

K = 0,0152 Btu/jam.ft^2.^{o}f/ft (*table* 4 Hal 801)

= 5,095509

11. Condensation of steam

hi = $J_h \dfrac{k}{D_e}\left(\dfrac{c\mu}{k}\right)^{1/3}\Phi s$

hi/φs = 30,78363 Btu/jam.ft^2.^{o}f

karena viskositas rendah, maka asumsi

ϕs = 1

ho = $\dfrac{h_a}{\varphi_s} \, x \, \varphi_s$

> The heat-transfer coefficients associated with the condensation of steam are very high compared with any which have been studied so far. It is customary to adopt a conventional and conservative value for the film coefficient, since it is never the controlling film, rather than obtain one by calculation. In this book in all heating services employing relatively air-free steam a value of 1500 Btu/(hr)(ft^2)(°F) will be used for the condensation of steam without regard to its location. Thus $h_i = h_o = h_{io} = 1500$.

ho = 30,78363 Btu/jam.ft^2.^{o}f

ho = 1.500 Btu/jam.ft^2.^{o}f

17. Pressure Drop : shell side

For NRe

NRe = 1.609,443022

f = 0,002 (*Fig* 29 Hal 839)

s = 0,94 (*Fig* 6 Hal 809)

Ds = 1,1042 ft

2. No of crosses

N + 1 = 12 L/B (Pers 7.44 Hal 151)

= 38,4

3. ΔPs

ΔPs = $\dfrac{f\ G_s^2\ D_s(N+1)}{5.22x10^{10} D_{e's} \Phi_s}$

a = 5453842,296

b = 52200000000

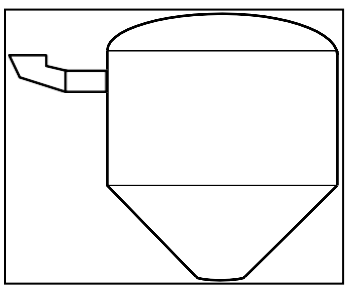
c = 0,077584926

d = 1

ΔPs = 1,83091E+25 psi

10.3.3 Reaktor

Fungsi	:	Tempat mereaksikan asam lemak dan KOH untuk mendapatkan sabun cair
Tipe	:	Silinder vertikal dengan alas dan tutup Ellipsoidal
Tekanan	:	1 atm
Suhu	:	80 ℃
Jenis reactor	:	CSTR Reaktor
Bahan konstruksi	:	*Stainless steel 18 Cr-8 Ni (SA -240 Grade 304)*
Jumlah	:	1 unit
Sifat bahan	:	Tidak volatil dan tidak korosif
Fasa	:	Cair



Gambar 10.3 Reaktor CSTR

Tabel 10.3 Data komponen pada reaktor CSTR

Komponen	**Massa (kg/jam)**	**%**	**ρ (kg/m³)**	**Viscositas (cp)**	**ρ campuran (kg/m³)**	**Viscositas campuran (cp)**
H2O	841,3288	0,3636032	849,15	0,9	308,7536573	0,32724288
C6H10O	0,1283	0,00554	774,07	0,9	0,042883478	0,00004990
C7H14O	0,0795	0,00344	641,39	0,77	0,022063816	2,64557E-05
C8H16O	0,3603	0,01557	674,94	0,56	0,105088158	8,71995E-05
C9H18O	0,0007	0,00003	685,89	0,89	0,000205767	0,000000267
C29H50O2	6,7004	0,28958	861	0,98	2,4932838	0,002837845
C12H24O2	0,0078	0,000337	759,4	7,3	0,00258196	2,46082E-05
C14H28O2	0,058	0,002507	762,06	5,83	0,019127706	0,000146136
C16H32O2	2,5026	0,10816	761,27	7,8	0,823389632	0,008436221

C18H34O2	1,9939	0,086172	774,32	8,6	0,667231544	0,007410777
C27H46O	10,7062	0,462698	1200,29	8,9	5,55374183	0,041180089
C18H32O2	0,5529	0,02390	776,94	9,3	0,18568866	0,002222243
C18H36O2	0,2432	0,010511	764,68	9,87	0,080367868	0,001037391
C30H50	5,3604	0,23166	957,58	12	2,218329828	0,027799717
C57H104O6	73,2992	3,16782	774,32	9,87	24,52906382	0,312664313
KOH	15,0485	0,65036	2120	8,3	13,787632	0,053980044
C12H23O2K	1,8487	0,07990	1100	1,26	0,8789	0,001006697
K2CO3	5,2766	0,22804	2430	1,6	5,541372	0,003648683
C14H27O2K	13,4209	0,58002	1100	1,26	6,38023	0,007308262
C16H31O2K	564,288	24,3872	1100	1,26	268,2597	0,307279287
C18H35O2K	54,6812	2,3632	1100	1,26	25,9952	0,029776285
C18H33O2K	578,9533	25,0210	1100	1,26	275,2315	0,315265179
C18H31O2K	124,5495	5,3827	1100	1,26	59,21021	0,067822604
C3H8O3	12,4764	0,5392	1260	17	6,793941	0,091664281
TOTAL	2313,8653	64			1007,575321	1,608917369

Laju alir : 2313,865 kg/jam = 5101,1468 lb/jam

Volumetrik : 2,2965 m^3/jam = 0,0225 ft^3.s

Viscositas : 1,68917369 cp = 0,0011 lb/ft.s

Densitas : 1007,5755 kg/m^3 = 62,90293847 lb/ft^3

1. Kapasitas tangki

Pelarutan untuk 1 hari

Vp = v × t reaksi = 30 menit

= 0,5 jam

Vp = 1,14825 m^3

Vp = m/ρ

Vp = 1,14825 m^3/jam

2. Faktor keamanan 20 % **0,2 peter plant design, 37**

$$V_P = 0.80\, V_T$$

$$V_T = \frac{V_P}{0.80}$$

= 1,4353125 m^3 379,1693738 gal

1,00 m^3 264,17 gal

3.Dimensi tangki

volume silinder, vs

$$V_s = \frac{\pi}{4}\ x\ D_t^2\ x\ H_s$$
$$V_s = \frac{\pi}{4}\ x\,1.5\ D_t^3$$

Hs = 1,5 Dt

volume ellipsoidal

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

ve = 0,1308 × D^3t

He = 0,25 Dt

Diameter tangki

$$V_t = V_s + 2\,V_e$$
$$V_t = \left(\frac{\pi}{4}\ x\,1.5\ D_t^3\right) + 2\left(0.1308\ x\ D_t^3\right)$$
$$V_t = 1.4391\ x\ D_t^3$$
$$D_t^3 = \frac{V_t}{1.4391}$$

Vt = vs + 2*ve

Dt = 0,999122033 m

Nilai per = 1,4391

Dt = 3,277120267 ft

akar 3 = 0,3333

Dt = 39,33543442 in

Tinggi tangki

Hs = 1,5

Hs = 1,498683 m

Tinggi ellipsoidal

He = 0,25 Dt

He = 0,24978 m

Pd = 16,95307 Psi Tekanan Desain

R = 19,66771721 in (Jari - jari) R = 1/2 D

S = 18700 Psi (allowable stress) *Peters - plant Design & Economic for Chemical Engineering Tabel 4*

E = 0,85 Joint efficiency

C = 0,02 in/tahun

Tahun digunakan = 10 tahun

Tebal dinding tangki

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

td = 0,220990355 in

Tebal dinding ellipsoidal

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

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

Item	Thickness t (in.)	Pressure p (psi)	Stress S (psi)	Notes
Cylindrical shell	$\frac{PR}{SE-0.6P}$	$\frac{SEt}{R+0.6t}$	$\frac{P(R+0.6t)}{t}$	$t \le 0.25D, P \le 0.385SE$
Flat flanged head (a)	$D\sqrt{0.3P/S}$	$t^2S/0.3D^2$	$0.3D^2P/t^2$	
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.

Walas-Chemical Process Equipment, Tabel 18.4

te = 0,22097916 in

Tinggi tangki total

$$H_t = t\ silinder + (2\ x\ t\ ellipsoidal)$$

Ht = Hs + (2x HE)

Ht = 1,998244065 m

Tinggi cairan Hc

$$H_c = \frac{V_c x (H_s + 2H_e)}{V_t}$$

Hc = 1,198946439 m

Tekanan hidrostatik

Pc = ρgH g = 9,81

Pc = 11850,76506 kg/m.s^2

Tekanan desain

Pd = Pop + pc

Pd =1,11495 atm

Desain pengaduk

Viskositas umpan < 4000 cP, maka dipilih propeller berdaun tiga (kec 1800 rpm)

Diameter pengaduk (d)

$$d = \frac{D_t}{3}$$

d = 0,333040678 m

Tinggi pengaduk dari dasar tangki, E

$$E = \frac{D_t / 3}{3}$$

E = 0,333040678 m

Panjang daun pengaduk (L)

$$L = \frac{d}{4}$$

L= 0,083260169 m

Lebar *baffle (J)*

$$J = \frac{D_t}{12}$$

J = 0,083260169 m

Lebar daun pengaduk (W)

$$W = \frac{d}{5}$$

W = 0,066608136 m

Kecepatan putar pengaduk (N)

$$\frac{Nd}{\left(\frac{\sigma\ g_C}{\rho}\right)^{0.25}} = 1.22 + 1.25\left(\frac{D}{d}\right)$$

Robert Trybal Mass Transfer Operation, Per6 -18

σ = 0,05 lb/ft

N = 2,489923693

gc = 32,2 ft/s^2

Daya pengadukkan

$$N_{\mathrm{Re}} = \frac{\rho N d^2}{\mu}$$

Nre = 169905,155

karena *Nre > 10000,* maka

$$P = \frac{K_T N^3 d^5 \rho}{gc}$$

KT = 0,087

P = 40,80826314

P = 0,074196842 Hp

Efisiensi motor :

Daya motor = 0,092746053

≈ **0,092746053 Hp**

Desain Pendingin

T umpan = 30 °c 86 °F

T steam = 242 °c 467,6 °F

p steam = 2,669 kg/m^3 0,16662567 lb/Ft^3

massa steam (m) = 46,00388282 kg/jam 101,4201601 lb/jam

volume (v) = 17,23637423 m^3/jam 608,6853196 ft^3/jam

ΔQ = 19285,14 kkal/jam 76523,43552 btu/jam

Dt = 381,60 °F

karena massa steam lebih kecil dari massa umpan maka digunakan jacket

46,00388282 ≤

Luas permukaan perpindahan panas

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

A =2,848481704 ft^2

Ud = 400 w/m^2 *engineeringpage.com*

= 70,4 Btu/ft^2 f.hr

Tinggi jacket :

$$H_j = H_c + te + jarak\ \ jacket$$

Asumsi jarak jacket = 5 in

0,127000254

Hj = 52,42350047 in

Volume steam :

$$V_s = \frac{m\ steam}{\rho\ steam}$$

Vs = 17,23637423 m3/jam

Diameter jacket, Dj

Diameter tangki :

$$D_r = D_t + (2\ x\ t_d)$$

Dr = 39,77741513 in

Diameter luar jacket :

$$D_j = D_r + (2\ x\ jarak\ jacket)$$

Dj = 49,77741513 in

Dj = 1,264348873 m

Tekanan hidrostatik pada jacket :

Ph = ρgH

Ph = 65,13431582 kg/m.s^2

Tekanan desain :

Pd = Pop + Ph

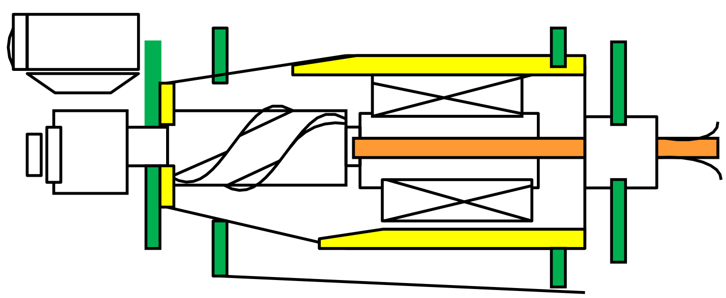
Pd = 1,000406002 atm

Tebal dinding jaket

Dj – Dr (m)

= 0,254048873 m

10.4 Decanter Centrifuge



Gambar 10. 4 *Decanter centrifuge*

Tabel 10.4 Data Komponen input

Komponen	Massa (kg/jam)	%	ρ (kg/m³)	Viscositas (cp)	ρ campuran (kg/m³)	Viscositas campuran (cp)
H_2O	841,3288	36,36031%	1000	0,9	363,6032	0,32724288
$C_6H_{10}O$	0,1283	0,00554%	851	0,9	0,0471454	0,00004986
$C_7H_{14}O$	0,0795	0,00344%	832	0,77	0,0286208	0,000026488
$C_8H_{16}O$	0,3603	0,01557%	821	0,56	0,1278297	0,000087192
$C_9H_{18}O$	0,0007	0,00003%	826	0,89	0,0002478	0,000000267
$C_{29}H_{50}O_2$	6,7004	0,28958%	950	0,98	2,75101	0,002837884
$C_{12}H_{24}O_2$	0,0078	0,00034%	883	7,3	0,0030022	0,00002482
$C_{14}H_{28}O_2$	0,0580	0,00251%	862	5,83	0,0216362	0,000146333
$C_{16}H_{32}O_2$	2,5026	0,10816%	850	7,8	0,91936	0,00843648
$C_{18}H_{34}O_2$	1,9939	0,08617%	895	8,6	0,7712215	0,00741062
$C_{27}H_{46}O$	10,7062	0,46270%	1067	8,9	4,937009	0,0411803
$C_{18}H_{32}O_2$	0,5529	0,02390%	902	9,3	0,215578	0,0022227
$C_{18}H_{36}O_2$	0,2432	0,01051%	860	9,87	0,090386	0,001037337
$C_{30}H_{50}$	5,3604	0,23166%	858	12	1,9876428	0,0277992
$C_{57}H_{104}O_6$	73,2992	3,16782%	915	9,87	28,985553	0,312663834
KOH	15,0485	0,65036%	2120	8,3	13,787632	0,05397988
K_2CO_3	5,2766	0,22804%	2430	1,6	5,541372	0,00364864
C12H23O2K	1,8487	0,07990%	1100	1,26	635,95587	0,728458542
C14H27O2K	13,4209	0,58002%	1100	1,26	635,95587	0,728458542
C16H31O2K	564,2880	24,38725%	1100	1,26	635,95587	0,728458542
C18H35O2K	54,6812	2,36320%	1100	1,26	635,95587	0,728458542
C18H33O2K	578,9533	25,02105%	1100	1,26	635,95587	0,728458542
C18H31O2K	124,5495	5,38275%	1100	1,26	635,95587	0,728458542
C3H8O3	12,4764	0,53920%	1260	17	6,79392	0,091664
Total	2313,8652	100%			1066,568236	1,608917257

Tabel 10.5 Data Komponen produk bawah *(Heavy phase)*

Komponen	Massa (kg/jam)	%	ρ (kg/m³)	Viscositas (cp)	ρ campuran (kg/m³)	Viscositas campuran (cp)
H_2O	824,5022	37,52478%	1000	0,9	375,2478099	0,3377230
$C_6H_{10}O$	0,1257	0,00572%	851	0,9	0,0486894	0,0000515
$C_7H_{14}O$	0,0779	0,00355%	832	0,77	0,0295129	0,0000273
$C_8H_{16}O$	0,3531	0,01607%	821	0,56	0,1319274	0,0000900
$C_9H_{18}O$	0,0007	0,00003%	826	0,89	0,0002586	0,0000003
$C_{29}H_{50}O_2$	6,5664	0,29885%	950	0,98	2,8390822	0,0029287
$C_{12}H_{24}O_2$	0,0077	0,00035%	883	7,3	0,0030847	0,0000255
$C_{14}H_{28}O_2$	0,0568	0,00259%	862	5,83	0,0222986	0,0001508
$C_{16}H_{32}O_2$	2,4526	0,11162%	850	7,8	0,9487877	0,0087065
$C_{18}H_{34}O_2$	1,9540	0,08893%	895	8,6	0,7959353	0,0076481
$C_{27}H_{46}O$	10,4920	0,47751%	1067	8,9	5,0950719	0,0424987
$C_{18}H_{32}O_2$	0,5419	0,02466%	902	9,3	0,2224415	0,0022935
$C_{18}H_{36}O_2$	0,2383	0,01085%	860	9,87	0,0932685	0,0010704
$C_{30}H_{50}$	5,2532	0,23908%	858	12	2,0513264	0,0286899
$C_{57}H_{104}O_6$	1,4660	0,06672%	915	9,87	0,6104869	0,0065853
KOH	14,7476	0,67119%	2120	8,3	14,2292562	0,0557089
K_2CO_3	5,1710	0,23534%	2430	1,6	5,7188787	0,0037655
C12H23O2K	1,8117	0,08245%	1100	1,26	656,3225194	0,7517876
C14H27O2K	13,1525	0,59860%	1100	1,26	656,3225194	0,7517876
C16H31O2K	553,0023	25,16826%	1100	1,26	656,3225194	0,7517876
C18H35O2K	53,5875	2,43888%	1100	1,26	656,3225194	0,7517876
C18H33O2K	567,3742	25,82236%	1100	1,26	656,3225194	0,7517876
C18H31O2K	122,0585	5,55513%	1100	1,26	656,3225194	0,7517876
C3H8O3	12,2268	0,55647%	1260	17	7,0114941	0,0945995
Total	2313,8652	100%			**1071,4221304**	**1,3443510**

Tabel 10.6 Data komponen produk atas *(Light phase)*

Komponen	Massa (kg/jam)	%	ρ (kg/m³)	Viscositas (cp)	ρ campuran (kg/m³)	Viscositas campuran (cp)
H_2O	16,82658	14,42552%	1000	0,9	144,2552206	0,129829699
$C_6H_{10}O$	0,00257	0,00220%	851	0,9	0,018717514	1,97953E-05
$C_7H_{14}O$	0,00159	0,00136%	832	0,77	0,01134555	1,05001E-05
$C_8H_{16}O$	0,00721	0,00618%	821	0,56	0,050716413	3,45934E-05
$C_9H_{18}O$	0,00001	0,00001%	826	0,89	9,94062E-05	1,07108E-07
$C_{29}H_{50}O_2$	0,13401	0,11489%	950	0,98	1,091418559	0,001125884
$C_{12}H_{24}O_2$	0,00016	0,00013%	883	7,3	0,001185835	9,80362E-06
$C_{14}H_{28}O_2$	0,00116	0,00099%	862	5,83	0,00857218	5,79766E-05
$C_{16}H_{32}O_2$	0,05005	0,04291%	850	7,8	0,364739195	0,0029401
$C_{18}H_{34}O_2$	0,03988	0,03419%	895	8,6	0,305978674	0,016337638
$C_{27}H_{46}O$	0,21412	0,18357%	1067	8,9	1,958680905	0,000881669
$C_{18}H_{32}O_2$	0,01106	0,00948%	902	9,3	0,085512409	0,000411497
$C_{18}H_{36}O_2$	0,00486	0,00417%	860	9,87	0,035854888	0,011029152
$C_{30}H_{50}$	0,10721	0,09191%	858	12	0,788584342	6,078241507
$C_{57}H_{104}O_6$	71,83317	61,58299%	915	9,87	563,484395	0,000411497
KOH	0,30097	0,25802%	2120	8,3	5,470103853	0,021415973
K_2CO_3	0,10553	0,09047%	2430	1,6	2,198488814	0,001447565
C12H23O2K	0,03697	0,03170%	1100	1,26	252,3078012	0,289007118
C14H27O2K	0,26842	0,23012%	1100	1,26	252,3078012	0,289007118
C16H31O2K	11,28576	9,67535%	1100	1,26	252,3078012	0,289007118
C18H35O2K	1,09362	0,93757%	1100	1,26	252,3078012	0,289007118
C18H33O2K	11,57907	9,92680%	1100	1,26	252,3078012	0,289007118
C18H31O2K	2,49099	2,13554%	1100	1,26	252,3078012	0,289007118
C3H8O3	0,24953	0,21392%	1260	17	2,695404471	0,036366568
Total	**116,6445**	**100%**			**975,1328**	**6,5925**

Laju alir massa = 2313,8652 kg/jam

Laju alir volumetrik umpan = 2,1694 m^3/jam

Jenis = *Continous gravity decanter*

Light phase = C57H104O6 Triolein Fase terdispersi

Laju alir volumetric = 0,1196 m^3/jam

Densitas = 975,1327 kg/m3

Viscositas = 6,5923 cp

Heavy phase = Sabun Cair Fase continue

Laju alir volumetric = 2,0508 m^3/jam

Densitas = 1071,4219 kg/m3

Viskositas = 1,3444 cp

Penentuan fase terdispersi

Walas, 645

Which phase is the dispersed one can be identified with the factor

$$\psi = \frac{Q_L}{Q_H}\left(\frac{\rho_L \mu_H}{\rho_H \mu_L}\right)^{0.3} \quad (18.5)$$

with the statements of this table (Selker and Schleicher, 1965):

ψ	Result
< 0.3	light phase always dispersed
0.3–0.5	light phase probably dispersed
0.5–2.0	phase inversion probable, design for worst case
2.0–3.3	heavy phase probably dispersed
3.3	heavy phase always dispersed

Ψ = 0,0352 fasa ringan selalu terdispersi sehingga fase berat menjadi fase kontinu.

Menentukan kecepatan pemisahan

Stokes' law (see Volume 2, Chapter 3) is used to determine the settling velocity of the droplets:

$$u_d = \frac{d_d^2 g(\rho_d - \rho_c)}{18\mu_c} \quad (10.7)$$

where d_d = droplet diameter, m,
u_d = settling (terminal) velocity of the dispersed phase droplets with diameter d, m/s,
ρ_c = density of the continuous phase, kg/m^3,
ρ_d = density of the dispersed phase, kg/m^3,
μ_c = viscosity of the continuous phase, N s/m^2,
g = gravitational acceleration, 9.81 m/s^2.

Equation 10.7 is used to calculate the settling velocity with an assumed droplet size of 150 μm, which is well below the droplet sizes normally found in decanter feeds. If the calculated settling velocity is greater than 4×10^{-3} m/s, then a figure of 4×10^{-3} m/s is used.

Couldson, 442

d_d = 150 um

= 0,00015 m

Viskosity Heavy Phase = Laju alir volumetrik = 1,3444 cp

= 0,0013 N.s/m^2

U_d = -9,0827,E-04 m/s

Nilai kecepatan pemisahan pemisahan (ud) bernilai negative karena butiran yang terdispersi (fase ringan) bergerak berlawanan dengan arah grafitasi Uc < Ud,

maka Uc maksimal = Ud

The decanter vessel is sized on the basis that the velocity of the continuous phase must be less than settling velocity of the droplets of the dispersed phase. Plug flow is assumed, and the velocity of the continuous phase calculated using the area of the interface:

$$u_c = \frac{L_c}{A_i} < u_d \quad (10.6)$$

where u_d = settling velocity of the dispersed phase droplets, m/s,
u_c = velocity of the continuous phase, m/s,
L_c = continuous phase volumetric flow rate, m^3/s,
A_i = area of the interface, m^2.

Lc = 17,1440 m^3/jam

= 5,E-03 m3/s

Waktu pemisahan

$$t = \frac{100\mu}{\rho_A - \rho_B} \qquad (2.15)$$

where t = separation time, h
ρ_A, ρ_B = densities of liquids A and B, kg/m^3
μ = viscosity of the continuous phase, cP

t = 1,3962 jam

= 83,7726 menit

= 5026,3581 detik

Menentukan panjang dan Diameter

$$u_c = \frac{L_c}{A_i} < u_d \qquad (10.6)$$

where u_d = settling velocity of the dispersed phase droplets, m/s,
u_c = velocity of the continuous phase, m/s,
L_c = continuous phase volumetric flow rate, m^3/s,
A_i = area of the interface, m^2.

Ai = 5,2432,E+00 jam

Vessel radius "r" is as so putting value of interfacial area we get.

$$r = \sqrt{\frac{A_i}{\pi}}$$

r = 1,2922 m

D = 2,584423 m

Diambil L/D = 3

L = 7,753269 m

Liquid Hold Up Volume

Liquid Hold Up Volume: To calculate hold up volume we have the relation as follows[10]
Liquid Hold Up Volume = tL_c (5)

Here: t = Separation time 4.23min L_C = Continuous Phase volumetric flow rate 0.232m^3/sec.

= 3,029007 m^3

Vessel should be 95 % full so that its volume jika tanpa piringan samping kiri dan kanan.

Volume of vessel = 3,1884 m^3

(*b*) The fraction of the tank volume occupied by the liquid will be 95 percent, and for a horizontal cylinder this means that the liquid depth will be 90 percent of the tank diameter.[4a] Thus

ZT = 2,32598 m

Liquid interface is 50% between vessel floor and liquid surface,

ZA1= 1,2922 m

ZB = 1,0338 m

ZA2 = ZA1 + (ZT-ZA1)*(ph/pl)

ZA2 = 2,2650 m

$$Z_B\rho_B + Z_{A1}\rho_A = Z_{A2}\rho_A \quad (2.12)$$

Solving Eq. (2.12) for Z_{A1} gives

$$Z_{A1} = Z_{A2} - Z_B\frac{\rho_B}{\rho_A} = Z_{A2} - (Z_T - Z_{A1})\frac{\rho_B}{\rho_A} \quad (2.13)$$

where the total depth of liquid in the vessel is $Z_T = Z_B + Z_{A1}$. From this

$$Z_{A1} = \frac{Z_{A2} - Z_T(\rho_B/\rho_A)}{1 - \rho_B/\rho_A} \quad (2.14)$$

Menghitung dimensi tangki

Kapasitas tangki

Vp = 3,1884 m^3

Faktor keamanan = 0,2 Peter plant design hal 38

Vt = 3,9855 m^3

Dimensi tangki

Diameter = 2,584423 m

Panjang = 7,753269 m

Tutup kiri dan kanan = ellipsoidal

Panjang ellipsoidal

Le = 0,25 D

Le = 0,64611 m

Panjang total

Lt = Ls + 2 Le Stainless stell

Lt = 9,04548 m

Pd = 14,7 Psi

R = 50,8744 in

S = 13700 *Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*

E = 0,85

C = 0,02

Tahun di gunakan = 10 tahun

Tebal dinding tangki

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

Walas-Chemical Process Equipment, Tabel 18.4

td = 0,006712 m

td = 6,712449 mm

Tebal dinding *ellipsoidal*

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

Walas-Chemical Process Equipment, Tabel 18.4

te = 0,00671 m

te = 6,711419 mm

10.5 **Tangki pencampuran sabun dengan minyak kayu manis**

Fungsi : Tempat pencampuran sabun dengan minyak kayu manis

Tipe : Silinder vertical dengan alas datar dan tutup ellipsoidal

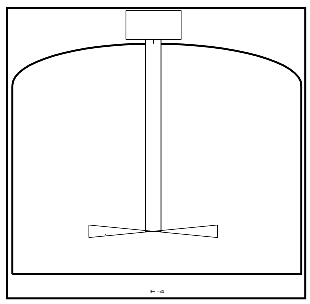
Bahan Konst ruksi : *Carbon steel (SA-515), Grade 55 C-SI*

Jumlah : 1 Unit

Fasa : Cair

Tekanan :1 Atm

Gambar :



Tabel 10.4 Data komponen pada storage tank 2

Komponen	**Massa (kg/jam)**	**ρ (kg/m³)**	**V (m³/jam)**	**U (Cp)**	**Xi**	**ρ Campuran (kg/m³)**	**U camparan (cp)**	**%**
H_2O	861,7891	1000	0,861789	0,9	0,34127	341,2685	0,3071417	34,12685%
$C_6H_{10}O$	0,1257	851	0,000148	0,9	0,00005	0,0424	0,0000448	0,00498%
$C_7H_{14}O$	0,0779	832	0,000094	0,77	0,00003	0,0256	0,0000237	0,00308%
$C_8H_{16}O$	0,3531	821	0,000430	0,56	0,00014	0,1148	0,0000783	0,01398%
$C_9H_{18}O$	0,0007	826	0,000001	0,89	0,00000	0,0002	0,0000003	0,00003%
$C_{29}H_{50}O_2$	6,5664	950	0,006912	0,98	0,00260	2,4703	0,0025483	0,26003%
$C_{12}H_{24}O_2$	0,0077	883	0,000009	7,3	0,00000	0,0026	0,0000219	0,00030%

C14H28O2	0,0568	862	0,000066	5,83	0,00002	0,0194	0,0001312	0,00225 %
C16H32O2	2,4526	850	0,002885	7,8	0,00097	0,8255	0,0075754	0,09712 %
C18H34O2	1,954	895	0,002183	8,6	0,00077	0,6926	0,0066547	0,07738 %
C27H46O	10,492	1067	0,009833	8,9	0,00415	4,4332	0,0369777	0,41548 %
C18H32O2	0,5419	902	0,000601	9,3	0,00021	0,1936	0,0019958	0,02146 %
C18H36O2	0,2383	860	0,000277	9,87	0,00009	0,0812	0,0009317	0,00944 %
C30H50	5,2532	858	0,006123	12	0,00208	1,7849	0,0249636	0,20803 %
C57H104O6	1,466	915	0,001602	9,87	0,00058	0,5312	0,0057295	0,05805 %
KOH	14,7476	2120	0,006956	8,3	0,00584	12,3808	0,0484720	0,58400 %
K2CO3	5,171	2430	0,002128	1,6	0,00205	4,9759	0,0032763	0,20477 %
C12H23O2K	1,8117	1100	1,191806	1,26	0,00072	571,0658	0,6541299	0,07174 %
C14H27O2K	13,1525	1100	1,191806	1,26	0,00521	571,0658	0,6541299	0,52084 %
C16H31O2K	553,0023	1100	1,191806	1,26	0,21899	571,0658	0,6541299	21,89889%
C18H35O2K	53,5875	1100	1,191806	1,26	0,02122	571,0658	0,6541299	2,12206 %
C18H33O2K	567,3742	1100	1,191806	1,26	0,22468	571,0658	0,6541299	22,46802%
C18H31O2K	122,0585	1100	1,191806	1,26	0,04834	571,0658	0,6541299	4,83352 %
C3H8O3	230,8503	1260	5,458083	17	0,09142	115,1850	1,5540839	9,14167 %
C10H16N2O8	4,3505	860	197,678428	20	0,00172	1,4816	0,0344560	0,17228 %
C13H9C13N2O	21,5328	1936	89,909348	23,9	0,00853	16,5083	0,2037953	0,85270 %
C16H10N2Na2O7S2	21,9722	800	36,409645	28,9	0,00870	6,9608	0,2514589	0,87010 %

C19H38N2O3	19,2257	1040	54,09425 9	14,9	0,00761	7,9179	0,1134397	0,7613 4%
C9H8O	5,0404	1048	207,9200 06	1,02	0,00200	2,0918	0,0020359	0,1996 0%
Total	**2525,2526**		**385,6436 06**		**1,0000**	**1091,0539**	**3,2599665**	100%

Laju alir : 2525,253 kg/jam

: 5567,1728 lb/jam

Volumetrik : 385,6436 m^3/jam

: 3,782949 ft^3/s

Viscositas : 3,2600 cp

: 0,0022 lb/ft.s

Densitas : 1091,0539 kg/m^3

: 68,11449498 lb/ft^3

1. Kapasitas tangki

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

Pelarutan untuk 1 hari : 0,5 jam = 30 menit

Vp = 1,157254 m^3

Vp = 40,8672681 ft^3

Faktor keamanan 20% peter plant design, 37

$$V_p = 0.9\,V_T$$
$$V_T = \frac{V_P}{0.9}$$

Volume tangki = 1,446567511 m^3

Vt = 51,0840851 ft^3

2. Dimensi tangki

a. Volume silinder

$$V_s = \frac{\pi}{4}\ x\ D_t^2\ x\ H_s$$
$$V_s = \frac{\pi}{4}\ x\, 1.5\ D_t^3$$

Hs = 1,5 Dt

b. Volume ellipsoidal

$$V_e = \frac{\pi}{6}\ x\ D_t^2\ x\ H_e$$

$$V_e = 0.1308\ x\ D_t^3$$

He = ¼ Dt

c. Diameter tangki

$$V_t = V_s + 2\,V_e$$
$$V_t = \left(\frac{\pi}{4}\ x\,1.5\ D_t^3\right) + 2\left(0.1308\ x\ D_t^3\right)$$
$$V_t = 1.4391\ x\ D_t^3$$
$$D_t^3 = \frac{V_t}{1.4391}$$

D^3 = 1,005189015 m^3

Dt = 1,001726516 m

Nilai per = 1,4391

akar 3 = 0,3333

d. Tinggi tangki

Hs = 1,5 Dt

HS = 1,502589774 m

e. Tinggi ellipsoidal

He = ¼ Dt

He = 0,25043 m

Pd = 16,840334 psi (Tekanan desain)

R = 19,718986 in/jari - jari R = ½ D

S = 17500 Psi *Petters - Plant Design & Economics for Chemical Engineering Tabel 4*

E = 0,85 Joint efficiency

C = 0,02 in/tahun

Tahun digunakan = 10 tahun

f. Tebal dinding tangki

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

Walas – chemical proces equipment table 18.4

td = 0,2223395 in 1 meter = 39,37 in

td = 0,0056474 m

g. Tebal dinding ellipsoidal

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

Walas Chemical process equipment table 18,4

te = 0,222326851 in 1 meter = 39,37 in

te = 0,005647113 m

h. Tinggi tangki

Ht = Hs + (2 x He)

Ht = 2,003453 m

i. Tinggi cairan (Hc)

$$H_c = \frac{V_c x (H_s + H_e)}{V_t}$$

Hc = 1,4024171 m

j. Tekanan hidrostatik

Pc = ρgH

Pc = 15010,4053 kg/m s^2 g = 9,81

Pc = 0,145600931 atm 1 kgf/m^2

k. Tekanan desain

Pd = Pop + Pc

Pd = 1,145601 atm 1 atm = 14,7 psi

Pd = 16,84033 psi

Desain pengaduk

Viscositas umpan < 4000 cP, maka dipilih propeller berdaun tiga (kecepatan 1800 rpm)

Diameter pengaduk (d)

$$d = \frac{D_t}{3}$$

d = 0,33390884 m

Tinggi pengaduk dari dasar tangki (E)

$$E = \frac{D_t / 3}{3}$$

E = 0,333908839 m

Panjang daun pengaduk (L)

$$L = \frac{d}{4}$$

Lebar baffle (J)

$$J = \frac{D_t}{12}$$

L= 0,08347721 m J = 0,08347721 m

Lebar daun pengaduk (W)

$$W = \frac{d}{5}$$

W = 0,06678177 m

Kecepatan putar pengaduk (N)

$$\frac{Nd}{\left(\frac{\sigma g_c}{\rho}\right)^{0.25}} = 1.22 + 1.25\left(\frac{D}{d}\right)$$

Robert Treybal – Mass Transfer Operation Pers.

σ = 0,05 lb/ft g_c = 32,2 ft/s^2

N = 2,45646691 rps

Daya pengadukan

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

Nre = 91228,6601 Turbulen

karena Nre > 10000, maka

$$P = \frac{K_T N^3 d}{gc}$$

KT = 0,87 Table 9.3 mc.cabe

P = 42,9877259 ft.lbf/s 1 HP = 550 ft.lbf/s

P = 0,0781595 Hp

***Efisiensi motor* = 80% = 0,8**

Daya motor = 0,09769938

≈ 0,5 Hp

BAB XI. KESIMPULAN DAN SARAN

11.1 Kesimpulan

Berdasarkan uraian dan hasil perhitungan dari bab – bab sebelumnya pada pra rancangan pabrik Sabun cair beraroma kayu manis dari *palm fatty acid distillate* dapat disimpulkan sebagai berikut :

1. Pra Rancangan Pabrik Sabun Cair Beraroma Kayu Manis dari *Palm Fatty Acid Distillate* dengan Kapasitas Produksi 20.000 ton/tahun direncanakan untuk memenuhi kebutuhan dalam negeri.
2. Dari analisa teknis dan ekonomi yang dilakukan, maka Pabrik Sabun Cair Beraroma Kayu Manis dari *Palm Fatty Acid Distillate* dengan Kapasitas Produksi 20.000 ton/tahun layak didirikan di Tanjung Palas, Dumai Timur, Riau.
3. Pra Rancangan Pabrik Sabun Cair Beraroma Kayu Manis dari *Palm Fatty Acid Distillate* dengan Kapasitas Produksi 20.000 merupakan perusahaan berbentuk Perseroan Terbatas (PT) dengan struktur organisasi *line and staff* dengan jumlah tenaga kerja 123 orang yang terdiri dari 97 karyawan *shift* dan 26 orang karyawan *non shift*.
4. Dari perhitungan analisa ekonomi, maka Pabrik Sabun Cair Beraroma Kayu Manis dari *Palm Fatty Acid Distillate* dengan Kapasitas Produksi 20.000 ini layak didirikan dengan :
   - *Fixed Capital Investment (FCI)* = US$ 54.324.092,72
     = Rp 792.612.958.675,18
   - *Working Capital Investment (WCI)* = US$ 9.586.604,60
     = Rp 139.872.875.060,33
   - *Total Capital Investment (TCI)* = US$ 63.910.672,32
     = Rp 932.485.833.735,50
   - *Total Sales (TS)* = US$ 65.916.280,62
     = Rp 961.748.196.625,96

- *Rate of Return (ROR)* = 46%.
- *Pay of Time (POT)* = 2 tahun 6 bulan 15 hari
- *Break Event Point (BEP)* = 17%

11.1 Saran

Berdasarkan pertimbangan dari analisa ekonomi yang telah dilakukan Pabrik Sabun Cair Beraroma Kayu Manis dari *Palm Fatty Acid Distillate* ini layak untuk dilanjutkan ke tahap rancangan. Untuk itu disarankan kepada pengurus dan pemilik modal untuk dapat mempertimbangkan dan mengkaji ulang tentang pendirian Pabrik Sabun Cair Beraroma Kayu Manis dari *Palm Fatty Acid Distillate*.

LAMPIRAN A. NERACA MASSA

Kapasitas produksi = 20.000 ton/tahun

$$= 20.000 \frac{\text{ton}}{\text{tahun}} \times \frac{1 \text{ tahun}}{330 \text{ hari}} \times \frac{1 \text{ hari}}{24 \text{ jam}} \times \frac{1000 \text{ kg}}{1 \text{ ton}}$$

= 2.525,2525 kg/jam

Operasi Pabrik = 330 hari/tahun

Basis perhitungan = 1000 kg/jam

Kapasitas Produksi Basis = 1.882,3645 kg/jam

Faktor Pengali $= \frac{\text{Kapasitas Sebenarnya}}{\text{Kapasitas Basis}}$

$$= \frac{2.252,2525 \text{ kg/jam}}{1.882,3645 \text{ kg/jam}} = 1,3415$$

Bahan baku *Palm fatty acid distillate* = 1.000 kg/jam x 1,3415

= 1.341,5322 kg/jam

= 10.624,9350 ton/tahun

Bahan baku Kalium hidroksida = 196,6623 kg/jam x 1,3415

= 263,8288 kg/jam

= 2.089,5242 ton/tahun

Maka untuk memproduksi Sabun cair sebanyak 20.000 ton/ tahun dibutuhkan bahan baku *Palm fatty acid distillate* sebesar 1.341,5322 kg/jam dan Kalium hidroksida sebesar 263,8288 kg/jam.

Tabel A.1 Spesifikasi Bahan Baku PFAD

Parameter	Satuan	Spesifikasi
Wujud		Padat pada suhu ruang
Warna		Kekuningan
Densitas	g/cm^3	0,85-0,88
Titik lebur	^oC	48
Komposisi	% (w/w)	
Asam laurat		0,16
Asam miristat		0,98
Asam palmitat		38,75
Asam stearat		3,68
Asam oleat		29,90
Asam linoleat		8,23
Triolein		14,40
Vitamin E		0,50
Sterol		0,80
Squalen		0,40
Air		0,08
Octanal		0,47
Hexenal		1,31
Nonanal		0,001
2-Heptanone		0,34

Tabel A.2 Spesifikasi Bahan Baku KOH

Parameter	Satuan	Spesifikasi
Wujud		Padat
Warna		Putih
Densitas	g/cm^3	2,12
Komposisi	% (w/w)	
KOH		98
K_2CO_3		2

Tabel A.3 Spesifikasi Produk Sabun Cair

Parameter	Satuan	Spesifikasi
Wujud		Cairan Homogen
Warna		Khas
Bau		Khas
pH		6-8
Alkali bebas (KOH)	%	50-60
Densitas	gr/cm^3	1,01-1,10
Kadar air	%	28-35
Cemaran mikroba : Angka lempeng total	Koloni/gr	Maks 1×10^5

(Sumber : SNI 06-4085-1996)

1. *Storage Tank PFAD*

Fungsi : Menyimpan dan mencairkan *Palm fatty acid distillate (PFAD).*

Aliran 1 ⟶ [*Storage Tank* (ST-1011)] ⟶ Aliran 2

Kondisi Operasi:

- Temperatur : 60 °C
- Tekanan : 1 atm

Aliran 1 : *Palm fatty acid distillate* padat

Aliran 2 : *Palm fatty acid distillate* cair

Neraca massa total :

Aliran 1 = Aliran 2

$1.341,5322 \frac{kg}{jam} = 1.341,5322 \frac{kg}{jam}$

Neraca massa komponen :

- **Input**

- Aliran 1

1) $H_2O_{(l)}$ $= 0,08\% \times 1.341,5322 \frac{kg}{jam} = 1,0732 \frac{kg}{jam}$

2) $C_6H_{10}O_{(s)}$ $= 1,31\% \times 1.341,5322 \frac{kg}{jam} = 17,5472 \frac{kg}{jam}$

3) $C_7H_{14}O_{(s)}$ $= 0,34\% \times 1.341,5322 \frac{kg}{jam} = 4,5623 \frac{kg}{jam}$

4) $C_8H_{16}O_{(s)}$ $= 0,47\% \times 1.341,5322 \frac{kg}{jam} = 6,3170 \frac{kg}{jam}$

5) $C_9H_{18}O_{(s)}$ $= 0,001\% \times 1.341,5322 \frac{kg}{jam} = 0,0140 \frac{kg}{jam}$

6) $C_{29}H_{50}O_{2(s)}$ $= 0,5\% \times 1.341,5322 \frac{kg}{jam} = 6,7077 \frac{kg}{jam}$

7) $C_{12}H_{24}O_{2(s)}$ $= 0,16\% \times 1.341,5322 \frac{kg}{jam} = 2,1921 \frac{kg}{jam}$

8) $C_{14}H_{28}O_{2(s)}$ $= 0,98\% \times 1.341,5322 \frac{kg}{jam} = 13,1524 \frac{kg}{jam}$

9) $C_{16}H_{32}O_{2(s)}$ $= 38,75\% \times 1.341,5322 \frac{kg}{jam} = 519,8479 \frac{kg}{jam}$

10) $C_{18}H_{34}O_{2(s)}$ $= 29,90\% \times 1.341,5322 \frac{kg}{jam} = 401,1476 \frac{kg}{jam}$

11) $C_{27}H_{46}O_{(s)}$ $= 0,8\% \times 1.341,5322 \frac{kg}{jam} = 10,7323 \frac{kg}{jam}$

12) $C_{18}H_{32}O_{2(s)}$ $= 8,23\% \times 1.341,5322 \frac{kg}{jam} = 110,3704 \frac{kg}{jam}$

13) $C_{18}H_{36}O_{2(s)}$ $= 3,68\% \times 1.341,5322 \frac{kg}{jam} = 49,3214 \frac{kg}{jam}$

14) $C_{30}H_{50(s)}$ $= 0,40\% \times 1.341,5322 \frac{kg}{jam} = 5,3661 \frac{kg}{jam}$

15) $C_{57}H_{104}O_{6(s)}$ $= 14,40\% \times 1.341,5322 \frac{kg}{jam} = 193,1806 \frac{kg}{jam}$

- **Output**

- Aliran 2

1) $H_2O_{(l)}$ $= 0,08\% \times 1.341,5322 \frac{kg}{jam} = 1,0732 \frac{kg}{jam}$

2) $C_6H_{10}O_{(l)}$ $= 1,31\% \times 1.341,5322 \frac{kg}{jam} = 17,5472 \frac{kg}{jam}$

3) $C_7H_{14}O_{(l)}$ $= 0,34\% \times 1.341,5322 \frac{kg}{jam} = 4,5623 \frac{kg}{jam}$

4) $C_8H_{16}O_{(l)}$ $= 0,47\% \times 1.341,5322 \frac{kg}{jam} = 6,3170 \frac{kg}{jam}$

5) $C_9H_{18}O_{(l)}$ $= 0,001\% \times 1.341,5322 \frac{kg}{jam} = 0,0140 \frac{kg}{jam}$

6) $C_{29}H_{50}O_{2(l)}$ $= 0,5\% \times 1.341,5322 \frac{kg}{jam} = 6,7077 \frac{kg}{jam}$

7) $C_{12}H_{24}O_{2(l)}$ $= 0,16\% \times 1.341,5322 \frac{kg}{jam} = 2,1921 \frac{kg}{jam}$

8) $C_{14}H_{28}O_{2(l)}$ $= 0,98\% \times 1.341,5322 \frac{kg}{jam} = 13,1524 \frac{kg}{jam}$

9) $C_{16}H_{32}O_{2(l)}$ $= 38,75\% \times 1.341,5322 \frac{kg}{jam} = 519,8479 \frac{kg}{jam}$

10) $C_{18}H_{34}O_{2(l)}$ $= 29,90\% \times 1.341,5322 \frac{kg}{jam} = 401,1476 \frac{kg}{jam}$

11) $C_{27}H_{46}O_{(l)}$ $= 0,8\% \times 1.341,5322 \frac{kg}{jam} = 10,7323 \frac{kg}{jam}$

12) $C_{18}H_{32}O_{2(l)}$ $= 8,23\% \times 1.341,5322 \frac{kg}{jam} = 110,3704 \frac{kg}{jam}$

13) $C_{18}H_{36}O_{2(l)}$ $= 3,68\% \times 1.341,5322 \frac{kg}{jam} = 49,3214 \frac{kg}{jam}$

14) $C_{30}H_{50(l)}$ $= 0,40\% \times 1.341,5322 \frac{kg}{jam} = 5,3661 \frac{kg}{jam}$

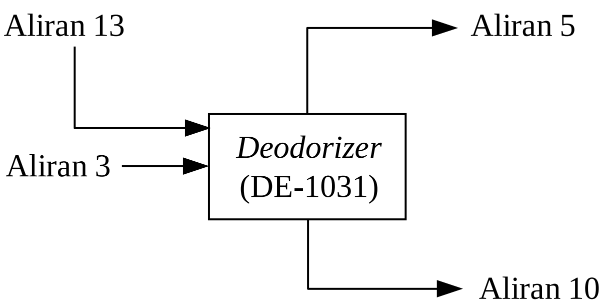
15) $C_{57}H_{104}O_{6(l)}$ $= 14,40\% \times 1.341,5322 \frac{kg}{jam} = 193,1806 \frac{kg}{jam}$

Tabel A.4 Neraca Massa *Storage Tank PFAD*

Komponen	Masuk		Keluar	
	Aliran 1		Aliran 2	
	Massa (kg/jam)	%	Massa (kg/jam)	%
H_2O	1,0732	0,0800%	1,0732	0,0800%
$C_6H_{10}O$	17,5472	1,3080%	17,5472	1,3080%
$C_7H_{14}O$	4,5623	0,3401%	4,5623	0,3401%
$C_8H_{16}O$	6,3170	0,4709%	6,3170	0,4709%
$C_9H_{18}O$	0,0140	0,0010%	0,0140	0,0010%
$C_{29}H_{50}O_2$	6,7077	0,5000%	6,7077	0,5000%
$C_{12}H_{24}O_2$	2,1921	0,1634%	2,1921	0,1634%
$C_{14}H_{28}O_2$	13,1524	0,9804%	13,1524	0,9804%
$C_{16}H_{32}O_2$	519,8479	38,7503%	519,8479	38,7503%
$C_{18}H_{34}O_2$	401,1476	29,9022%	401,1476	29,9022%
$C_{27}H_{46}O$	10,7323	0,8000%	10,7323	0,8000%
$C_{18}H_{32}O_2$	110,3704	8,2272%	110,3704	8,2272%
$C_{18}H_{36}O_2$	49,3214	3,6765%	49,3214	3,6765%
$C_{30}H_{50}$	5,3661	0,4000%	5,3661	0,4000%
$C_{57}H_{104}O_6$	193,1806	14,4000%	193,1806	14,4000%
Sub total	**1.341,5322**	**100%**	**1.341,5322**	**100%**
Total	**1.341,5322**		**1.341,5322**	

2. Deodorizer

Fungsi : Memisahkan *Palm fatty acid distillate (PFAD)* dari komponen-komponen yang menyebabkan bau.



Direncanakan:

1. Zat bau (Hexenal, Octanal, Nonanal, 2-Heptanone) sebagai overhead 95% keluar sebagai destilat.
2. Asam lemak dan komponen lain terpisah sebagai bottom produk 95%.
3. Feed masuk kolom pada kondisi jenuhnya.

Kondisi Operasi:

- Temperatur : 226 °C
- Tekanan : 0,008 atm

Aliran 3 : Umpan dari *Storage tank PFAD*

Aliran 4 : Produk atas

Aliran 5 : Produk bawah

Data :

Tabel A.5 Data Umpan Deodorizer

Komponen	BM	Masuk (kg/jam)	Masuk (kmol/jam)	Fraksi Mol (X_i)	Titik Didih (°C)
H_2O	18	1,0732	0,0596	0,01271	100
$C_6H_{10}O$	98	17,5472	0,1791	0,03815	126
$C_7H_{14}O$	114	4,5623	0,0400	0,00853	151
$C_8H_{16}O$	128	6,3170	0,0494	0,01052	171
$C_9H_{18}O$	142	0,0140	0,0001	0,00002	195
$C_{29}H_{50}O_2$	430	6,7077	0,0156	0,00332	235
$C_{12}H_{24}O_2$	200	2,1921	0,0110	0,00234	298,9
$C_{14}H_{28}O_2$	228	13,1524	0,0577	0,01229	326,2
$C_{16}H_{32}O_2$	256	519,8479	2,0307	0,43271	351,5
$C_{18}H_{34}O_2$	282	401,1476	1,4225	0,30312	360
$C_{27}H_{46}O$	386	10,7323	0,0278	0,00592	360
$C_{18}H_{32}O_2$	280	110,3704	0,3942	0,08400	365,2
$C_{18}H_{36}O_2$	284	49,3214	0,1737	0,03701	383
$C_{30}H_{20}$	410	5,3661	0,0131	0,00279	421,3
$C_{57}H_{104}O_6$	884	193,1806	0,2185	0,04657	554,2
Total		**1.341,5322**	**4,6928**	**1,00000**	

Persamaan Antoine,

$$P_i = \text{Exp}\left(\text{Ant A} - \frac{\text{Ant B}}{T + \text{Ant C}}\right)$$

Dimana :T dalam °C

P dalam mmHg

Penentuan relative volatilitas komponen kunci berdasarkan persamaan 4.6 Halaman 119, *Process Plant Design, J.R Backhurst et al, 1973*.

$$\alpha = \frac{K_i}{K_{HK}}$$

K_i = tiap komponen feed

K_{HK} = K tiap komponen *Heavy Key* (HK)

Komponen kunci berat (HK) dan komponen kunci ringan (LK)

Heavy Key	Light Key
$C_{16}H_{32}O_2$	$C_9H_{18}O$

Trial, T = 226 °C = 499 K

P_{total} = 6 mmHg = 0,008 atm

Tabel A.6 Trial Temperatur Operasi *Deodorizer*

Komponen	X_i	Ant A	Ant B	Ant C	P_i	$K_i = P_i/P_t$	$Y_i = K_i . X_i$
H_2O	0,01271	8,0557	1723,6452	233,080	73,9006	12,1547	0,1544
$C_6H_{10}O$	0,03815	7,9753	1778,0682	215,337	51,8445	8,5271	0,3253
$C_7H_{14}O$	0,00853	7,4052	1651,0950	214,078	38,6691	6,3601	0,0542
$C_8H_{16}O$	0,01052	7,2381	1718,7642	204,356	25,6886	4,2251	0,0444
$C_9H_{18}O$	0,00002	7,8947	1969,9988	201,854	26,9078	4,4256	0,0001
$C_{29}H_{50}O_2$	0,00332	6,0958	1588,8163	35,862	1,0334	0,1700	0,0006
$C_{12}H_{24}O_2$	0,00234	7,7412	2288,3705	172,970	7,4502	1,2254	0,0029
$C_{14}H_{28}O_2$	0,01229	7,7131	2374,5031	165,381	5,2021	0,8556	0,0105
$C_{16}H_{32}O_2$	0,43271	8,1718	2631,4566	158,347	3,7758	0,6210	0,2687
$C_{18}H_{34}O_2$	0,30312	7,5165	2527,0832	147,227	2,1150	0,3479	0,1054
$C_{27}H_{46}O$	0,00592	6,4653	1807,4985	67,180	1,3555	0,2229	0,0013
$C_{18}H_{32}O_2$	0,08400	7,7174	2751,4556	135,614	1,1191	0,1841	0,0155
$C_{18}H_{36}O_2$	0,03701	7,9363	2634,1040	151,509	2,6174	0,4305	0,0159
$C_{30}H_{20}$	0,00279	7,0678	2505,5413	129,852	1,0311	0,1696	0,0005
$C_{57}H_{104}O_6$	0,04657	6,6758	2618,4473	40,000	0,0424	0,0070	0,0003
Total	**1,00000**				**242,7532**	**39,9265**	**1,0000**

1. **Heavy Key, HK ($C_{16}H_{32}O_2$)**

   Distribusi komponen kunci 95%

   - $C_{16}H_{32}O_2$ di Distilat

     = 5% x 2,0307 kmol/jam = 0,1015 kmol/jam

     = 0,1015 kmol/jam x 256 kg/kmol = 25,9924 kg/jam

   - $C_{16}H_{32}O_2$ di Bottom

     = 95% x 2,0307 kmol/jam = 1,9291 kmol/jam

     = 1,9291 kmol/jam x 256 kg/kmol = 493,8555 kg/jam

Total = 519,8479 kg/jam

Log id/ib = $\log \frac{25{,}9924 \text{ kg/jam}}{493{,}8555 \text{ kg/jam}} = -1{,}2788$

2. Light Key, LK ($C_9H_{18}O$)

Distribusi komponen kunci 95%

- $C_9H_{18}O$ di Distilat

  = 95% x 0,0001 kmol/jam = 0,00009 kmol/jam

  = 0,00009 kmol/jam x 142 kg/kmol = 0,0133 kg/jam

- $C_9H_{18}O$ di Bottom

  = 5% x 0,0001 kmol/jam = 0,000005 kmol/jam

  = 0,000005 kmol/jam x 142 kg/kmol = 0,0007 kg/jam

Total = 0,0295 kg/jam

Log id/ib = $\log \frac{0{,}0133 \text{ kg/jam}}{0{,}0007 \text{ kg/jam}} = 1{,}2788$

Tabel A.7 Perhitungan Relatif Volatilitas

Komponen	K_i	$a_i = Ki/K_{Hk}$	log a_i	log id/ib	id/ib
H_2O	12,1547	19,5722	1,2916		
$C_6H_{10}O$	8,5271	13,7309	1,1377		
$C_7H_{14}O$	6,3601	10,2413	1,0104		
$C_8H_{16}O$	4,2251	6,8035	0,8327		
$C_9H_{18}O$	**4,4256**	**7,1264**	**0,8529**	**1,2788**	**3,5922**
$C_{29}H_{50}O_2$	0,1700	0,2737	-0,5627		
$C_{12}H_{24}O_2$	1,2254	1,9731	0,2952		
$C_{14}H_{28}O_2$	0,8556	1,3778	0,1392		
$C_{16}H_{32}O_2$	**0,6210**	**1,0000**	**0,0000**	**-1,2788**	**0,2784**
$C_{18}H_{34}O_2$	0,3479	0,5601	-0,2517		
$C_{27}H_{46}O$	0,2229	0,3590	-0,4449		
$C_{18}H_{32}O_2$	0,1841	0,2964	-0,5281		
$C_{18}H_{36}O_2$	0,4305	0,6932	-0,1591		
$C_{30}H_{20}$	0,1696	0,2731	-0,5637		
$C_{57}H_{104}O_6$	0,0070	0,0112	-1,9498		
Total	**39,9265**	**64,2919**	**1,0995**		

Penentuan distribusi masing-masing komponen berdasarkan persamaan Van Winkle, halaman 345, *Distillation, Matthew Van Winkle, 1967.*

$$\log \alpha = m\left(\log id/ib\right) + b \qquad ...1$$

$$m = \frac{\left(\log \alpha_i\right)_{LK} - \left(\log \alpha_i\right)_{HK}}{\left(\log id/ib\right)_{LK} - \left(\log id/ib\right)_{HK}} \qquad ...2$$

$$m = \frac{0{,}8529 - 0{,}0000}{1{,}2788 - (-1{,}2788)} = 0{,}3335$$

$$b = \left(\log \alpha_i\right)_{LK} - m\left(\log id/ib\right)_{LK} \qquad ...3$$

b = 0,8529 – 0,4264

b = 0,4264

Persamaan menjadi,

$$\text{Log id/ib} = \frac{\left(\log\alpha_i - b\right)}{m}$$

1. **H_2O**

   $\text{Log id/ib} = \frac{1{,}2916 - 0{,}4264}{0{,}3335} = 393{,}0918$

   H_2O di bottom = $\frac{0{,}0596}{393{,}0918 + 1{,}0000}$ = 0,0002 kmol/jam = 0,0027 kg/jam

   H_2O di destilat = 0,0596 – 0,0002 = 0,0595 kmol/jam = 1,0705 kg/jam

2. **$C_6H_{10}O$**

   $\text{Log id/ib} = \frac{1{,}1377 - 0{,}4264}{0{,}3335} = 135{,}7901$

   $C_6H_{10}O$ di bottom = $\frac{0{,}1791}{135{,}7901 + 1{,}0000}$ = 0,0013 kmol/jam = 0,1283 kg/jam

   $C_6H_{10}O$ di destilat = 0,1791 – 0,0013 = 0,1777 kmol/jam = 17,4189 kg/jam

3. **$C_7H_{14}O$**

   $\text{Log id/ib} = \frac{1{,}0104 - 0{,}4264}{0{,}3335} = 56{,}3647$

   $C_7H_{14}O$ di bottom = $\frac{0{,}0400}{56{,}3647 + 1{,}0000}$ = 0,0007 kmol/jam = 0,0795 kg/jam

   $C_7H_{14}O$ di destilat = 0,0400 – 0,0007 = 0,0393 kmol/jam = 4,4827 kg/jam

4. **$C_8H_{16}O$**

   $\text{Log id/ib} = \frac{0{,}8327 - 0{,}4264}{0{,}3335} = 16{,}5336$

   $C_8H_{16}O$ di bottom = $\frac{0{,}0494}{16{,}5336 + 1{,}0000}$ = 0,0028 kmol/jam = 0,3603 kg/jam

   $C_8H_{16}O$ di destilat = 0,0494 – 0,0028 = 0,0465 kmol/jam = 5,9567 kg/jam

5. $C_9H_{18}O$

Log id/ib = $\frac{0,8529 - 0,4264}{0,3335}$ = 19

$C_8H_{16}O$ di bottom = $\frac{0,0001}{19 + 1,0000}$ = 0,000005 kmol/jam = 0,0007 kg/jam

$C_8H_{16}O$ di destilat = 0,0001 – 0,0000005 = 0,0001 kmol/jam = 0,0133 kg/jam

6. $C_{29}H_{50}O_2$

Log id/ib = $\frac{-0,5627 - 0,4264}{0,3335}$ = 0,0011

$C_{29}H_{50}O_2$ di bottom = $\frac{0,0156}{0,0011 + 1,0000}$ = 0,0156 kmol/jam = 6,7004 kg/jam

$C_{29}H_{50}O_2$ di destilat = 0,0156 – 0,0156 = 0,00002 kmol/jam = 0,0072 kg/jam

7. $C_{12}H_{24}O_2$

Log id/ib = $\frac{0,2952 - 0,4264}{0,3335}$ = 0,4040

$C_{12}H_{24}O_2$ di bottom = $\frac{0,0110}{0,4040 + 1,0000}$ = 0,0078 kmol/jam = 1,5613 kg/jam

$C_{12}H_{24}O_2$ di destilat = 0,0110 – 0,0078 = 0,0032 kmol/jam = 0,6307 kg/jam

8. $C_{14}H_{28}O_2$

Log id/ib = $\frac{0,1392 - 0,4264}{0,3335}$ = 0,1376

$C_{14}H_{28}O_2$ di bottom = $\frac{0,0577}{0,1376 + 1,0000}$ = 0,0507 kmol/jam = 11,5616 kg/jam

$C_{14}H_{28}O_2$ di destilat = 0,0577 – 0,0507 = 0,0070 kmol/jam = 1,5908 kg/jam

9. $C_{16}H_{32}O_2$

Log id/ib = $\frac{0,0000 - 0,4264}{0,3335}$ = 0,0526

$C_{16}H_{32}O_2$ di bottom = $\frac{2,0307}{0,0526 + 1,0000}$ = 1,9291 kmol/jam = 493,8555 kg/jam

$C_{16}H_{32}O_2$ di destilat = 2,0307 – 1,9291 = 0,1015 kmol/jam = 25,9924 kg/jam

10. $C_{18}H_{34}O_2$

Log id/ib = $\frac{-0,2517 - 0,4264}{0,3335}$ = 0,0093

$C_{18}H_{34}O_2$ di bottom = $\frac{1,4225}{0,0093 + 1,0000}$ = 1,4095 kmol/jam = 197,4683 kg/jam

$C_{18}H_{34}O_2$ di destilat = 1,4225 – 1,4095 = 0,0130 kmol/jam = 3,6793 kg/jam

11. $C_{27}H_{46}O$

Log id/ib = $\frac{-0,4449 - 0,4264}{0,3335}$ = 0,0024

$C_{27}H_{46}O$ di bottom = $\frac{0,0278}{0,0024 + 1,0000}$ = 0,0277 kmol/jam = 10,7062 kg/jam

$C_{27}H_{46}O$ di destilat = 0,0278 – 0,0277 = 0,0001 kmol/jam = 0,0261 kg/jam

12. $C_{18}H_{32}O_2$

Log id/ib = $\frac{-0,5281 - 0,4264}{0,3335}$ = 0,0014

$C_{18}H_{32}O_2$ di bottom = $\frac{0,3942}{0,0014 + 1,0000}$ = 0,3936 kmol/jam = 110,2191 kg/jam

$C_{18}H_{32}O_2$ di destilat = 0,3942 – 0,3936 = 0,0005 kmol/jam = 0,1513 kg/jam

13. $C_{18}H_{36}O_2$

Log id/ib = $\frac{-0,1591 - 0,4264}{0,3335}$ = 0,0175

$C_{18}H_{36}O_2$ di bottom = $\frac{0,1737}{0,0175 + 1,0000}$ = 0,1707 kmol/jam = 48,4713 kg/jam

$C_{18}H_{36}O_2$ di destilat = 0,1737 – 0,1707 = 0,0030 kmol/jam = 0,8502 kg/jam

14. $C_{30}H_{50}$

Log id/ib = $\frac{-0,5637 - 0,4264}{0,3335}$ = 0,0011

$C_{30}H_{50}$ di bottom = $\frac{0,01319}{0,0011 + 1,0000}$ = 0,01307 kmol/jam = 5,3604 kg/jam

$C_{30}H_{50}$ di destilat = 0,01319 – 0,01307 = 0,00002 kmol/jam = 0,0058 kg/jam

15. $C_{57}H_{104}O_6$

Log id/ib = $\frac{-1,9498 - 0,4264}{0,3335}$ = 7×10^{-8}

$C_{57}H_{104}O_6$ di bottom = $\frac{0,2185301}{7 \times 10^{-8} + 1,0000}$ = 0,2185301 kmol/jam = 191,1806 kg/jam

$C_{57}H_{104}O_6$ di destilat = 0,21853013 – 0,2185301 = 0,00000002 kmol/jam = 0,00001 kg/jam

- **Kondisi Top (*Dew Point*)**

T = 196 °C = 469 K

P = 6 mmHg = 0,008 atm

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	X_D	P_i (mmHg)	K_i	$Y_i = X_D/K_i$
$H_2O_{(g)}$	18	1,0705	0,0595	0,1317	56,9992	9,3749	0,0141
$C_6H_{10}O_{(g)}$	98	17,4189	0,1777	0,3937	38,7683	6,3764	0,0617
$C_7H_{14}O_{(g)}$	114	4,4827	0,0393	0,0871	29,4749	4,8478	0,0180
$C_8H_{16}O_{(g)}$	128	5,9567	0,0465	0,1031	19,1065	3,1425	0,0328
$C_9H_{18}O_{(g)}$	142	0,0133	0,0001	0,0002	19,0868	3,1393	0,0001
$C_{29}H_{50}O_{2(g)}$	430	0,0072	0,00002	0,00004	0,4758	0,0783	0,0005
$C_{12}H_{24}O_{2(g)}$	200	0,6307	0,0032	0,0070	4,6974	0,7726	0,0090
$C_{14}H_{28}O_{2(g)}$	228	1,5908	0,0070	0,0155	3,1613	0,5199	0,0297
$C_{16}H_{32}O_{2(g)}$	256	25,9924	0,1015	0,2249	2,1284	0,3501	0,6424
$C_{18}H_{34}O_{2(g)}$	282	3,6793	0,0130	0,0289	1,1780	0,1937	0,1491
$C_{27}H_{46}O_{(g)}$	402	0,0261	0,0001	0,0001	0,6768	0,1113	0,0013
$C_{18}H_{32}O_{2(g)}$	280	0,1513	0,0005	0,0012	0,5666	0,0932	0,0128
$C_{18}H_{36}O_{2(g)}$	284	0,8502	0,0030	0,0066	1,4427	0,2373	0,0279
$C_{30}H_{20(g)}$	410	0,0058	0,00001	0,00003	0,5432	0,0893	0,0003
$C_{57}H_{104}O_{6(g)}$	884	0,00001	0,00000002	0,00000004	0,0123	0,0020	0,00002
Total		**61,8760**	**0,4515**	**1,0000**	**178,3180**	**29,3286**	**1,0000**

- **Kondisi Bottom (*Buble Point*)**

  T = 329 °C = 602 K

  P = 6 mmHg = 0,008 atm

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	Y_B	P_i (mmHg)	K_i	$X_i = Y_B/K_i$
$H_2O_{(l)}$	18	0,0027	0,0002	0,00004	146,9988	24,1774	0,000001
$C_6H_{10}O_{(l)}$	98	0,1283	0,0013	0,0003	111,0773	18,2693	0,00002
$C_7H_{14}O_{(l)}$	114	0,0795	0,0007	0,0002	78,7490	12,9521	0,00001
$C_8H_{16}O_{(l)}$	128	0,3603	0,0028	0,0007	55,5306	9,1333	0,00007
$C_9H_{18}O_{(l)}$	142	0,0007	0,000005	0,000001	65,7156	10,8085	0,0000001
$C_{29}H_{50}O_{2(l)}$	430	6,7004	0,0156	0,0037	5,7201	0,9408	0,0039
$C_{12}H_{24}O_{2(l)}$	200	1,5613	0,0078	0,0018	24,1550	3,9729	0,0005
$C_{14}H_{28}O_{2(l)}$	228	11,5616	0,0507	0,0120	18,3998	3,0263	0,0040
$C_{16}H_{32}O_{2(l)}$	256	493,8555	1,9291	0,4548	16,0347	2,6373	0,1725
$C_{18}H_{34}O_{2(l)}$	282	397,4683	1,4095	0,3323	9,1392	1,5032	0,2211
$C_{27}H_{46}O_{(l)}$	402	10,7062	0,0277	0,0065	6,7235	1,1058	0,0059
$C_{18}H_{32}O_{2(l)}$	280	110,2191	0,3936	0,0928	6,0389	0,9932	0,0934
$C_{18}H_{36}O_{2(l)}$	284	48,4713	0,1707	0,0402	11,6691	1,9193	0,0210
$C_{30}H_{20(l)}$	410	5,3604	0,0131	0,0031	5,0032	0,8229	0,0037
$C_{57}H_{104}O_{6(l)}$	884	193,1806	0,2185	0,0515	0,6597	0,1085	0,4748
Total		**1.279,6562**	**4,2413**	**1**	**561,6144**	**92,3708**	**1,0000**

Aliran 13

Sparging steam yang digunakan adalah sebanyak 1-5% **(3%)** terhadap umpan yang digunakan. Jadi steam yang digunakan adalah 3% x 1.341,5322 kg/jam = 40 kg/jam.

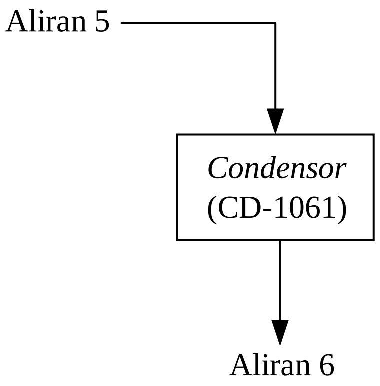
Tabel A.10 Neraca Massa Destilasi

Komponen	Masuk				Keluar			
	Aliran 3		Aliran 13		Aliran 5		Aliran 10	
	Massa (kg/jam)	%	Massa (kg/jam)	%	Massa (kg/jam)	%	Massa (kg/jam)	%
H_2O	1,0732	0,0800%			1,0705	1,0483%	0,0027	0,0002%
$C_6H_{10}O$	17,5472	1,3080%			17,4189	17,0570%	0,1283	0,0100%
$C_7H_{14}O$	4,5623	0,3401%			4,4827	4,3896%	0,0795	0,0062%
$C_8H_{16}O$	6,3170	0,4709%			5,9567	5,8329%	0,3603	0,0282%
$C_9H_{18}O$	0,0140	0,0010%			0,0133	0,0131%	0,0007	0,0001%
$C_{29}H_{50}O_2$	6,7077	0,5000%			0,0072	0,0071%	6,7004	0,5236%
$C_{12}H_{24}O_2$	2,1921	0,1634%			0,6307	0,6176%	1,5613	0,1220%
$C_{14}H_{28}O_2$	13,1524	0,9804%			1,5908	1,5577%	11,5616	0,9035%
$C_{16}H_{32}O_2$	519,8479	38,7503%			25,9924	25,4523%	493,8555	38,5928%
$C_{18}H_{34}O_2$	401,1476	29,9022%			3,6793	3,6029%	397,4683	31,0606%
$C_{27}H_{46}O$	10,7323	0,8000%			0,0261	0,0256%	10,7062	0,8366%
$C_{18}H_{32}O_2$	110,3704	8,2272%			0,1513	0,1481%	110,2191	8,6132%
$C_{18}H_{36}O_2$	49,3214	3,6765%			0,8502	0,8325%	48,4713	3,7878%
$C_{30}H_{20}$	5,3661	0,4000%			0,0058	0,0056%	5,3604	0,4189%
$C_{57}H_{104}O_6$	193,1806	14,4000%			0,00001	0,00001%	193,1806	15,0963%
Steam			40,2460	100%	40,2460	39,4097%		

Subtotal	**1.341,5322**	**100%**	**40,2460**	**100%**	**102,1219**	**100%**	**1.279,6562**	**100%**
Total	**1.381,7782**				**1.381,7782**			

3. *Condensor*

Fungsi : Menurunkan temperatur produk yang keluar dari bagian atas *Deodorizer* dan mengubah fasa destilat berupa uap menjadi cair.



Aliran 5 : Produk atas *Deodorizer* dengan fasa uap

Aliran 6 : Produk keluaran *Condensor* dengan fasa cair

Neraca massa total :

Aliran 5 = Aliran 6

$188{,}4572 \frac{kg}{jam} = 188{,}4572 \frac{kg}{jam}$

Neraca massa komponen :

- **Input**

- Aliran 5

1) $H_2O_{(g)}$ $= 1{,}04826\% \times 188{,}4572 \frac{kg}{jam} = 1{,}97552 \frac{kg}{jam}$
2) $C_6H_{10}O_{(g)}$ $= 17{,}05697\% \times 188{,}4572 \frac{kg}{jam} = 32{,}14150 \frac{kg}{jam}$
3) $C_7H_{14}O_{(g)}$ $= 4{,}38959\% \times 188{,}4572 \frac{kg}{jam} = 8{,}27251 \frac{kg}{jam}$
4) $C_8H_{16}O_{(g)}$ $= 5{,}83294\% \times 188{,}4572 \frac{kg}{jam} = 10{,}99259 \frac{kg}{jam}$
5) $C_9H_{18}O_{(g)}$ $= 0{,}01306\% \times 188{,}4572 \frac{kg}{jam} = 0{,}02461 \frac{kg}{jam}$
6) $C_{29}H_{50}O_{2(g)}$ $= 0{,}00709\% \times 188{,}4572 \frac{kg}{jam} = 0{,}01336 \frac{kg}{jam}$
7) $C_{12}H_{24}O_{2(g)}$ $= 0{,}61762\% \times 188{,}4572 \frac{kg}{jam} = 1{,}16394 \frac{kg}{jam}$
8) $C_{14}H_{28}O_{2(g)}$ $= 1{,}55772\% \times 188{,}4572 \frac{kg}{jam} = 2{,}93563 \frac{kg}{jam}$

9) $C_{16}H_{32}O_{2(g)}$ $= 24,45231\% \times 188,4572 \frac{kg}{jam} = 47,96672 \frac{kg}{jam}$

10) $C_{18}H_{34}O_{2(g)}$ $= 3,60289\% \times 188,4572 \frac{kg}{jam} = 6,78990 \frac{kg}{jam}$

11) $C_{27}H_{46}O_{(g)}$ $= 0,02556\% \times 188,4572 \frac{kg}{jam} = 0,04817 \frac{kg}{jam}$

12) $C_{18}H_{32}O_{2(g)}$ $= 0,14813\% \times 188,4572 \frac{kg}{jam} = 0,27916 \frac{kg}{jam}$

13) $C_{18}H_{36}O_{2(g)}$ $= 0,83251\% \times 188,4572 \frac{kg}{jam} = 1,56892 \frac{kg}{jam}$

14) $C_{30}H_{50(g)}$ $= 0,00564\% \times 188,4572 \frac{kg}{jam} = 0,01062 \frac{kg}{jam}$

15) $C_{57}H_{104}O_{6(g)}$ $= 0,00001\% \times 188,4572 \frac{kg}{jam} = 0,00003 \frac{kg}{jam}$

16) $Steam_{(g)}$ $= 39,40971\% \times 188,4572 \frac{kg}{jam} = 74,27046 \frac{kg}{jam}$

- **Output**

- Aliran 6

1) $H_2O_{(l)}$ $= 1,04826\% \times 188,4572 \frac{kg}{jam} = 1,97552 \frac{kg}{jam}$

2) $C_6H_{10}O_{(l)}$ $= 17,05697\% \times 188,4572 \frac{kg}{jam} = 32,14150 \frac{kg}{jam}$

3) $C_7H_{14}O_{(l)}$ $= 4,38959\% \times 188,4572 \frac{kg}{jam} = 8,27251 \frac{kg}{jam}$

4) $C_8H_{16}O_{(l)}$ $= 5,83294\% \times 188,4572 \frac{kg}{jam} = 10,99259 \frac{kg}{jam}$

5) $C_9H_{18}O_{(l)}$ $= 0,01306\% \times 188,4572 \frac{kg}{jam} = 0,02461 \frac{kg}{jam}$

6) $C_{29}H_{50}O_{2(l)}$ $= 0,00709\% \times 188,4572 \frac{kg}{jam} = 0,01336 \frac{kg}{jam}$

7) $C_{12}H_{24}O_{2(l)}$ $= 0,61762\% \times 188,4572 \frac{kg}{jam} = 1,16394 \frac{kg}{jam}$

8) $C_{14}H_{28}O_{2(l)}$ $= 1,55772\% \times 188,4572 \frac{kg}{jam} = 2,93563 \frac{kg}{jam}$

9) $C_{16}H_{32}O_{2(l)}$ $= 24,45231\% \times 188,4572 \frac{kg}{jam} = 47,96672 \frac{kg}{jam}$

10) $C_{18}H_{34}O_{2(l)}$ $= 3,60289\% \times 188,4572 \frac{kg}{jam} = 6,78990 \frac{kg}{jam}$

11) $C_{27}H_{46}O_{(l)}$ $= 0,02556\% \times 188,4572 \frac{kg}{jam} = 0,04817 \frac{kg}{jam}$

12) $C_{18}H_{32}O_{2(l)}$ $= 0,14813\% \times 188,4572 \frac{kg}{jam} = 0,27916 \frac{kg}{jam}$

13) $C_{18}H_{36}O_{2(l)}$ $= 0{,}83251\% \times 188{,}4572 \frac{kg}{jam} = 1{,}56892 \frac{kg}{jam}$

14) $C_{30}H_{50(l)}$ $= 0{,}00564\% \times 188{,}4572 \frac{kg}{jam} = 0{,}01062 \frac{kg}{jam}$

15) $C_{57}H_{104}O_{6(l)}$ $= 0{,}00001\% \times 188{,}4572 \frac{kg}{jam} = 0{,}00003 \frac{kg}{jam}$

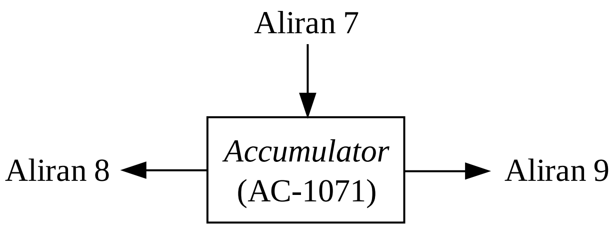
16) Kondensat$_{(l)}$ $= 39{,}40971\% \times 188{,}4572 \frac{kg}{jam} = 74{,}27046 \frac{kg}{jam}$

Tabel A.11 Neraca Massa *Condensor*

Komponen	**Masuk**		**Keluar**	
	Aliran 5		**Aliran 6**	
	Massa (kg/jam)	**%**	**Massa (kg/jam)**	**%**
H_2O	1,97552	1,04826%	1,97552	1,04826%
$C_6H_{10}O$	32,14510	17,05697%	32,14510	17,05697%
$C_7H_{14}O$	8,27251	4,38959%	8,27251	4,38959%
$C_8H_{16}O$	10,99259	5,83294%	10,99259	5,83294%
$C_9H_{18}O$	0,02461	0,01306%	0,02461	0,01306%
$C_{29}H_{50}O_2$	0,01336	0,00709%	0,01336	0,00709%
$C_{12}H_{24}O_2$	1,16394	0,61762%	1,16394	0,61762%
$C_{14}H_{28}O_2$	2,93563	1,55772%	2,93563	1,55772%
$C_{16}H_{32}O_2$	47,96672	25,45231%	47,96672	25,45231%
$C_{18}H_{34}O_2$	6,78990	3,60289%	6,78990	3,60289%
$C_{27}H_{46}O$	0,04817	0,02556%	0,04817	0,02556%
$C_{18}H_{32}O_2$	0,27916	0,14813%	0,27916	0,14813%
$C_{18}H_{36}O_2$	1,56892	0,83251%	1,56892	0,83251%
$C_{30}H_{50}$	0,01062	0,00564%	0,01062	0,00564%
$C_{57}H_{104}O_6$	0,00003	0,00001%	0,00003	0,00001%
Steam	74,27046	39,40971%		
Kondensat			74,27046	39,40971%
Subtotal	**188,45724**	**100%**	**188,45724**	**100%**
Total	**188,45724**		**188,45724**	

4. Accumulator

Fungsi : Mengumpulkan produk yang keluar dari *Condensor*.



Aliran 7 : Produk dari *Condensor*

Aliran 8 : *Reflux*

Aliran 9 : Destilat

Berdasarkan persamaan 9-115 halaman 404, *Mass Transfer Operations 3rd edition, Robert E. Treybal.*

Neraca massa total

G = L + D dengan L = R x D

Sehingga

G = (R x D) + D

G = D (R+1) dengan R = 0,8454 kmol/jam

G = 1,8454 D dengan D = 2,6874 kmol/jam

Kemudian dapat ditentukan jumlah mol di G, yaitu:

G = 1,8454 x 2,6874 kmol/jam = 4,9594 kmol/jam

L = 0,8454 kmol/jam x 2,6874 kmol/jam = 2,2720 kmol/jam

Komposisi Destilat (D)

Tabel A.12 Komposisi Destilat

Komponen	BM	Mol (kmol/jam)	Massa (kg/jam)	Fraksi Mol (X_D)
H_2O	18	0,05947236	1,07050247	0,02213008
$C_6H_{10}O$	98	0,17774398	17,41890999	0,06613977
$C_7H_{14}O$	114	0,03932226	4,48273792	0,01463209
$C_8H_{16}O$	128	0,04653678	5,95670820	0,01731666
$C_9H_{18}O$	142	0,00009391	0,01333586	0,00003495
$C_{29}H_{50}O_2$	430	0,00001684	0,00724209	0,00000627
$C_{12}H_{24}O_2$	200	0,00315361	0,63072191	0,00117348
$C_{14}H_{28}O_2$	228	0,00697706	1,59076943	0,00259621
$C_{16}H_{32}O_2$	256	0,10153279	25,99239427	0,03778106
$C_{18}H_{34}O_2$	282	0,01304730	3,67933846	0,00485499
$C_{27}H_{46}O$	386	0,00006763	0,02610334	0,00002516
$C_{18}H_{32}O_2$	280	0,00054026	0,15127237	0,00020103
$C_{18}H_{36}O_2$	284	0,00299356	0,85017207	0,00111393
$C_{30}H_{50}$	410	0,00001404	0,00575485	0,00000522
$C_{57}H_{104}O_6$	884	0,00000002	0,00001446	0,00000001
Kondensat	18	2,23588700	40,24596594	0,83198910
Total		**2,68739940**	**102,12194363**	**1,00000000**

Komposisi *Reflux* (L)

Tabel A.13 Komposisi *Reflux*

Komponen	BM	Mol (kmol/jam)	Massa (kg/jam)	Fraksi Mol (X_R)
H_2O	18	0,05027875	0,90501752	0,02213008
$C_6H_{10}O$	98	0,15026721	14,72618624	0,06613977
$C_7H_{14}O$	114	0,03324358	3,78976833	0,01463209
$C_8H_{16}O$	128	0,03934284	5,03588309	0,01731666
$C_9H_{18}O$	142	0,00007940	0,01127432	0,00003495
$C_{29}H_{50}O_2$	430	0,00001424	0,00612256	0,00000627
$C_{12}H_{24}O_2$	200	0,00266610	0,53322098	0,00117348
$C_{14}H_{28}O_2$	228	0,00589850	1,34485837	0,00259621
$C_{16}H_{32}O_2$	256	0,08583722	21,97432785	0,03778106
$C_{18}H_{34}O_2$	282	0,01103037	3,11056337	0,00485499
$C_{27}H_{46}O$	386	0,00005717	0,02206812	0,00002516
$C_{18}H_{32}O_2$	280	0,00045674	0,12788774	0,00020103
$C_{18}H_{36}O_2$	284	0,00253080	0,71874717	0,00111393
$C_{30}H_{50}$	410	0,00001187	0,00486523	0,00000522
$C_{57}H_{104}O_6$	884	0,00000001	0,00001223	0,00000001
Kondensat	18	1,89024964	34,02449350	0,83198910
Total		**2,27196444**	**86,33529664**	**1,00000000**

Komposisi *Feed* (G)

Tabel A.14 Komposisi *Feed*

Komponen	BM	Mol (kmol/jam)	Massa (kg/jam)	Fraksi Mol (X_G)
H_2O	18	0,10975111	1,97551999	0,02213008
$C_6H_{10}O$	98	0,32801119	32,14509622	0,06613977
$C_7H_{14}O$	114	0,07256584	8,27250626	0,01463209
$C_8H_{16}O$	128	0,08587962	10,99259130	0,01731666
$C_9H_{18}O$	142	0,00017331	0,02461019	0,00003495
$C_{29}H_{50}O_2$	430	0,00003108	0,01336465	0,00000627
$C_{12}H_{24}O_2$	200	0,00581971	1,16394288	0,00117348
$C_{14}H_{28}O_2$	228	0,01287556	2,93562781	0,00259621
$C_{16}H_{32}O_2$	256	0,18737001	47,96672212	0,03778106
$C_{18}H_{34}O_2$	282	0,02407767	6,78990182	0,00485499
$C_{27}H_{46}O$	386	0,00012480	0,04817146	0,00002516
$C_{18}H_{32}O_2$	280	0,00099700	0,27916011	0,00020103
$C_{18}H_{36}O_2$	284	0,00552436	1,56891924	0,00111393
$C_{30}H_{50}$	410	0,00002590	0,01062007	0,00000522
$C_{57}H_{104}O_6$	884	0,00000003	0,00002669	0,00000001

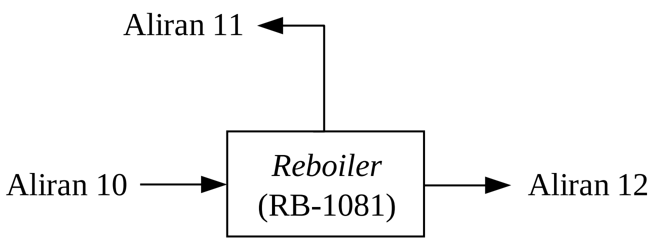
Kondensat	18	4,12613664	74,27045944	0,83198910
Total		**4,95936383**	**188,45724027**	**1,00000000**

Tabel A.15 Neraca Massa *Accumulator*

Komponen	Masuk		Keluar			
	Aliran 7		Aliran 8		Aliran 9	
	Massa (kg/jam)	%	Massa (kg/jam)	%	Massa (kg/jam)	%
H_2O	1,9755	1,0483%	0,9050	1,0483%	1,0705	1,0483%
$C_6H_{10}O$	32,1451	17,0570%	14,7262	17,0570%	17,4189	17,0570%
$C_7H_{14}O$	8,2725	4,3896%	3,7898	4,3896%	4,4827	4,3896%
$C_8H_{16}O$	10,9926	5,8329%	5,0359	5,8329%	5,9567	5,8329%
$C_9H_{18}O$	0,0246	0,0131%	0,0113	0,0131%	0,0133	0,0131%
$C_{29}H_{50}O_2$	0,0134	0,0071%	0,0061	0,0071%	0,0072	0,0071%
$C_{12}H_{24}O_2$	1,1639	0,6176%	0,5332	0,6176%	0,6307	0,6176%
$C_{14}H_{28}O_2$	2,9356	1,5577%	1,3449	1,5577%	1,5908	1,5577%
$C_{16}H_{32}O_2$	47,9667	25,4523%	21,9743	25,4523%	25,9924	25,4523%
$C_{18}H_{34}O_2$	6,7899	3,6029%	3,1106	3,6029%	3,6793	3,6029%
$C_{27}H_{46}O$	0,0482	0,0256%	0,0221	0,0256%	0,0261	0,0256%
$C_{18}H_{32}O_2$	0,2792	0,1481%	0,1279	0,1481%	0,1513	0,1481%
$C_{18}H_{36}O_2$	1,5689	0,8325%	0,7187	0,8325%	0,8502	0,8325%
$C_{30}H_{50}$	0,0106	0,0056%	0,0049	0,0056%	0,0058	0,0056%
$C_{57}H_{104}O_6$	0,00003	0,00001%	0,00001	0,00001%	0,00001	0,00001%
Kondensat	74,2705	0,3941	34,0245	0,3941	40,2460	0,3941
Subtotal	**188,4572**	**100%**	**86,3353**	**100%**	**102,1219**	**100%**
Total	**188,4572**		**188,4572**			

5. Reboiler

Fungsi : Menguapkan sebagian campuran produk bawah hingga ke titik didihnya sebelum masuk ke *Deodorizer.*



Aliran 10	: Umpan yang akan dipanaskan
Aliran 11	: Umpan yang telah dipanaskan
Aliran 12	: Produk hasil *Deodorizer*

Berdasarkan persamaan 9-119 halaman 405 sampai 406, *Mass Transfer Operations 3rd edition, Robert E. Treybal.*

Neraca massa total

L' = F + L

Diketahui :

F = 4,6928 kmol/jam (Umpan masuk destilasi)

L = 2,2720 kmol/jam (*Reflux* dari *accumulator*)

V = 4,9594 kmol/jam (Umpan dari *accumulator)*

L' = F + L

L' = (4,6928 + 2,2720) kmol/jam

L' = 6,9648 kmol/jam

Umpan pada kondisi *bubble point* maka q = 1

V' = F (q - 1) + V

V' = 4,6928 kmol/jam (1 – 1) + 4,9594 kmol/jam

V' = 4,9594 kmol/jam

B = L' – V'

B = 6,9648 kmol/jam – 4,9594 kmol/jam

B = 2,0054 kmol/jam

Komposisi *Feed Reboiler* (L')

Tabel A.16 Komposisi *Feed Reboiler*

Komponen	BM	Mol (kmol/jam)	Massa (kg/jam)	Fraksi Mol ($X_{L'}$)
H_2O	18	0,1099	1,9782	0,0013
$C_6H_{10}O$	98	0,3293	32,2734	0,0220
$C_7H_{14}O$	114	0,0733	8,3520	0,0057
$C_8H_{16}O$	128	0,0887	11,3529	0,0077
$C_9H_{18}O$	142	0,0002	0,0253	0,0000
$C_{29}H_{50}O_2$	430	0,0156	6,7138	0,0046

$C_{12}H_{24}O_2$	200	0,0136	2,7253	0,0019
$C_{14}H_{28}O_2$	228	0,0636	14,4972	0,0099
$C_{16}H_{32}O_2$	256	2,1165	541,8222	0,3691
$C_{18}H_{34}O_2$	282	1,4335	404,2582	0,2754
$C_{27}H_{46}O$	386	0,0279	10,7543	0,0073
$C_{18}H_{32}O_2$	280	0,3946	110,4983	0,0753
$C_{18}H_{36}O_2$	284	0,1762	50,0402	0,0341
$C_{30}H_{50}$	410	0,0131	5,3710	0,0037
$C_{57}H_{104}O_6$	884	0,2185	193,1806	0,1316
Kondensat	18	4,1261	74,2705	0,0506
Total		**9,2007**	**1.468,1135**	**1,0000**

Komposisi *Bottom Reboiler* (B)

Tabel A.17 Komposisi *Reflux*

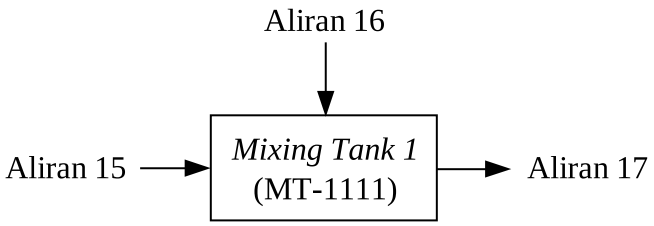
Komponen	BM	Mol (kmol/jam)	Massa (kg/jam)	Fraksi Mol (X_B)
H_2O	18	0,0002	0,0027	0,000002
$C_6H_{10}O$	98	0,0013	0,1283	0,000100
$C_7H_{14}O$	114	0,0007	0,0795	0,000062
$C_8H_{16}O$	128	0,0028	0,3603	0,000282
$C_9H_{18}O$	142	0,0000	0,0007	0,000001
$C_{29}H_{50}O_2$	430	0,0156	6,7004	0,005236
$C_{12}H_{24}O_2$	200	0,0078	1,5613	0,001220
$C_{14}H_{28}O_2$	228	0,0507	11,5616	0,009035
$C_{16}H_{32}O_2$	256	1,9291	493,8555	0,385928
$C_{18}H_{34}O_2$	282	1,4095	397,4683	0,310606
$C_{27}H_{46}O$	386	0,0277	10,7062	0,008366
$C_{18}H_{32}O_2$	280	0,3936	110,2191	0,086132
$C_{18}H_{36}O_2$	284	0,1707	48,4713	0,037878
$C_{30}H_{50}$	410	0,0131	5,3604	0,004189
$C_{57}H_{104}O_6$	884	0,2185	193,1806	0,150963
Total		**4,2413**	**1.279,6562**	**1,000000**

Tabel A.18 Neraca Massa *Reboiler*

Komponen	Masuk		Keluar			
	Aliran 10		Aliran 11		Aliran 12	
	kg/jam	%	kg/jam	%	kg/jam	%
H_2O	1,9782	0,1347%	1,9755	1,0483%	0,0027	0,0002%
$C_6H_{10}O$	32,2734	2,1983%	32,1451	17,0570%	0,1283	0,0100%
$C_7H_{14}O$	8,3520	0,5689%	8,2725	4,3896%	0,0795	0,0062%
$C_8H_{16}O$	11,3529	0,7733%	10,9926	5,8329%	0,3603	0,0282%
$C_9H_{18}O$	0,0253	0,0017%	0,0246	0,0131%	0,0007	0,0001%
$C_{29}H_{50}O_2$	6,7138	0,4573%	0,0134	0,0071%	6,7004	0,5236%
$C_{12}H_{24}O_2$	2,7253	0,1856%	1,1639	0,6176%	1,5613	0,1220%
$C_{14}H_{28}O_2$	14,4972	0,9875%	2,9356	1,5577%	11,5616	0,9035%
$C_{16}H_{32}O_2$	541,8222	36,9060%	47,9667	25,4523%	493,8555	38,5928%
$C_{18}H_{34}O_2$	404,2582	27,5359%	6,7899	3,6029%	397,4683	31,0606%
$C_{27}H_{46}O$	10,7543	0,7325%	0,0482	0,0256%	10,7062	0,8366%
$C_{18}H_{32}O_2$	110,4983	7,5265%	0,2792	0,1481%	110,2191	8,6132%
$C_{18}H_{36}O_2$	50,0402	3,4085%	1,5689	0,8325%	48,4713	3,7878%
$C_{30}H_{50}$	5,3710	0,3658%	0,0106	0,0056%	5,3604	0,4189%
$C_{57}H_{104}O_6$	193,1806	13,1584%	0,00003	0,00001%	193,1806	15,0963%
Kondensat	74,2705	5,0589%				
Steam			74,27046	39,40971%		
Sub total	**1.468,1135**	**100%**	**188,4572**	**100%**	**1.279,6562**	**100%**
Total	**1.468,1135**		**1.468,1135**			

6. Mixing Tank 1

Fungsi : Mencampurkan atau melarutkan Kalium hidroksida dengan air.



Kondisi Operasi:

- Temperatur : 30 °C
- Tekanan : 1 atm

Aliran 15 : Kalium hidroksida padat

Aliran 16 : Air

Aliran 17 : Kalium hidroksida 25%

Untuk menghitung kebutuhan Kalium hidroksida dilakukan perhitungan sesuai dengan reaksi yang berlangsung.

Laju alir *Palm fatty acid distillate* dari *bottom product deodorizer* adalah sebesar 1.279,6562 kg/jam.

- $C_{12}H_{24}O_2$ = 0,12%

  Konversi reaksi = 99%

	$C_{12}H_{24}O_{2\,(l)}$	+ $KOH_{(aq)}$	→ $C_{12}H_{23}O_2K_{(l)}$	+ $H_2O_{(l)}$
M	: 0,00781	0,00781		
B	: 0,00777	0,00777	0,00777	0,00777
S	: 0,00004	0,00004	0,00777	0,00777

Tabel A.20 Neraca Massa Asam Laurat

Komponen	BM	Masuk		Keluar	
		Mol (kmol/jam)	Massa (kg/jam)	Mol (kmol/jam)	Massa (kg/jam)
$C_{12}H_{24}O_2$	200	0,00781	1,56134	0,00004	0,00783
KOH	56	0,00781	0,43718	0,00004	0,00219
$C_{12}H_{23}O_2K$	238			0,00777	1,84868
H_2O	18			0,00777	0,13982
Total		**0,01561**	**1,99852**	**0,01561**	**1,99852**

- $C_{14}H_{28}O_2$ = 0,90%

  Konversi reaksi = 99%

	$C_{14}H_{28}O_{2\,(l)}$	+ $KOH_{(aq)}$	→ $C_{14}H_{27}O_2K_{(l)}$	+ $H_2O_{(l)}$
M	: 0,05071	0,05071		
B	: 0,05045	0,05045	0,05045	0,05045
S	: 0,00025	0,00025	0,05045	0,05045

Tabel A.21 Neraca Massa Asam Miristat

Komponen	BM	Masuk		Keluar	
		Mol (kmol/jam)	Massa (kg/jam)	Mol (kmol/jam)	Massa (kg/jam)
$C_{14}H_{28}O_2$	228	0,05071	11,56161	0,00025	0,05800
KOH	56	0,05071	2,83969	0,00025	0,01425
$C_{14}H_{27}O_2K$	266			0,05045	13,42088
H_2O	18			0,05045	0,90818
Total		**0,10142**	**14,40131**	**0,10142**	**14,40131**

- $C_{16}H_{32}O_2$ = 38,59%

  Konversi reaksi = 99%

	$C_{16}H_{32}O_{2\,(l)}$	+ $KOH_{(aq)}$	→ $C_{16}H_{31}O_2K_{(l)}$	+ $H_2O_{(l)}$
M	: 1,92912	1,92912		
B	: 1,91935	1,91935	1,91935	1,91935
S	: 0,00978	0,00978	1,91935	1,91935

Tabel A.22 Neraca Massa Asam Palmitat

Komponen	BM	Masuk		Keluar	
		Mol (kmol/jam)	Massa (kg/jam)	Mol (kmol/jam)	Massa (kg/jam)
$C_{16}H_{32}O_2$	256	1,92912	493,85549	0,00978	2,50264
KOH	56	1,92912	108,03089	0,00978	0,54745
$C_{16}H_{31}O_2K$	294			1,91935	564,28804
H_2O	18			1,91935	34,54825
Total		**3,85825**	**601,88638**	**3,85825**	**601,88638**

- $C_{18}H_{36}O_2$ = 3,79%

  Konversi reaksi = 99%

	$C_{18}H_{36}O_{2\,(l)}$	+ $KOH_{(aq)}$	→ $C_{18}H_{35}O_2K_{(l)}$	+ $H_2O_{(l)}$
M	: 0,17067	0,17067		
B	: 0,16982	0,16982	0,16982	0,16982
S	: 0,00086	0,00086	0,16982	0,16982

Tabel A.23 Neraca Massa Asam Stearat

Komponen	BM	Masuk		Keluar	
		Mol (kmol/jam)	Massa (kg/jam)	Mol (kmol/jam)	Massa (kg/jam)
$C_{18}H_{36}O_2$	284	0,17067	48,47126	0,00086	0,24316
KOH	56	0,17067	9,55771	0,00086	0,04795
$C_{18}H_{35}O_2K$	322			0,16982	54,68116
H_2O	18			0,16982	3,05671
Total		**0,34135**	**58,02897**	**0,34135**	**58,02897**

- $C_{18}H_{34}O_2$ = 31,06%

  Konversi reaksi = 99%

	$C_{18}H_{34}O_{2\,(l)}$	+ $KOH_{(aq)}$	→ $C_{18}H_{33}O_2K_{(l)}$	+ $H_2O_{(l)}$
M	: 1,40946	1,40946		
B	: 1,40239	1,40239	1,40239	1,40239
S	: 0,00707	0,00707	1,40239	1,40239

Tabel A.24 Neraca Massa Asam Oleat

Komponen	BM	Masuk		Keluar	
		Mol (kmol/jam)	Massa (kg/jam)	Mol (kmol/jam)	Massa (kg/jam)
$C_{18}H_{34}O_2$	282	1,40946	397,46830	0,00707	1,99390
KOH	56	1,40946	78,92988	0,00707	0,39595
$C_{18}H_{33}O_2K$	320			1,40239	448,76528
H_2O	18			1,40239	25,24305
Total		2,81892	**476,39818**	2,81892	**476,39818**

- $C_{18}H_{32}O_2$ = 8,61%

  Konversi reaksi = 99%

	$C_{18}H_{32}O_{2\,(l)}$	+ $KOH_{(aq)}$	→ $C_{18}H_{31}O_2K_{(l)}$	+ $H_2O_{(l)}$
M	: 0,39364	0,39364		
B	: 0,39167	0,39167	0,39167	0,39167
S	: 0,00197	0,00197	0,39167	0,39167

Tabel A.25 Neraca Massa Asam Linoleat

Komponen	BM	Masuk		Keluar	
		Mol (kmol/jam)	Massa (kg/jam)	Mol (kmol/jam)	Massa (kg/jam)
$C_{18}H_{32}O_2$	280	0,39364	110,21913	0,00197	0,55291
KOH	56	0,39364	22,04383	0,00197	0,11058
$C_{18}H_{31}O_2K$	318			0,39167	124,54949
H_2O	18			0,39167	7,04997
Total		**0,78728**	**132,26296**	**0,78728**	**132,26296**

- $C_{57}H_{104}O_6$ = 15%

  Konversi reaksi = 62%

	$C_{57}H_{104}O_{6\,(l)}$	+ $3KOH_{(aq)}$	→ $3C_{18}H_{31}O_2K_{(l)}$	+ $3H_8O_{3(l)}$
M	: 0,21853	0,65559		
B	: 0,13561	0,40684	0,40684	0,13561
S	: 0,08292	0,24875	0,40684	0,13561

Tabel A.26 Neraca Massa Triolein

Komponen	BM	Masuk		Keluar	
		Mol (kmol/jam)	Massa (kg/jam)	Mol (kmol/jam)	Massa (kg/jam)
$C_{57}H_{104}O_6$	884	0,21853	193,18062	0,08292	73,29915
KOH	56	0,65559	36,71306	0,24875	13,93016
$C_{18}H_{33}O_2K$	320			0,40684	130,18802
$C_3H_8O_3$	92			0,13561	12,47635
Total		**0,87412**	**229,89368**	**0,87412**	**229,89368**

Berdasarkan hasil perhitungan reaksi diperoleh kebutuhan Kalium hidroksida sebanyak **258,5522 kg/jam.**

Sementara kemurnian Kalium hidroksida adalah 98%, maka kebutuhan total Kalium hidroksida adalah **258,5522 / 98% = 263,8288 kg/jam**

Kemudian berdasarkan ((Devi Silsia et al, 2017) konsentasi Kalium hidroksida yang baik adalah 25% karena menghasilkan sabun cair dengan viskositas, pH dan alkali bebas yang kecil.

Neraca massa total

Aliran 15 + Aliran 16 = Aliran 17

263,8288 kg/jam + Aliran 16 = Aliran 17

Neraca massa komponen

- **KOH**

% × Aliran 15 + % × Aliran 16 = % × Aliran 17

98% × 263,8288 kg/jam + 0 = 25% × Aliran 17

Aliran 17 = 1.034,2089 kg/jam

Neraca massa total

Aliran 15 + Aliran 16 = Aliran 17

263,8288 kg/jam + Aliran 16 = 1.034,2089 kg/jam

Aliran 16 = 770,3801 kg/jam

- **Input**

- Aliran 15
  1) $KOH_{(s)}$ $= 98\% \times 263,8288 \frac{kg}{jam} = 258,5522 \frac{kg}{jam}$
  2) $K_2CO_{3(s)}$ $= 2\% \times 263,8288 \frac{kg}{jam} = 5,2766 \frac{kg}{jam}$

- Aliran 16
  1) $H_2O_{(l)}$ $= 100\% \times 770,3801 \frac{kg}{jam} = 770,3801 \frac{kg}{jam}$

- **Output**

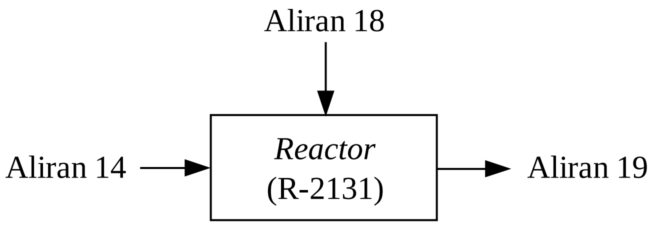
- Aliran 17
  1) $KOH_{(aq)}$ $= 25\% \times 1.034,2089 \frac{kg}{jam} = 258,5255 \frac{kg}{jam}$
  2) $K_2CO_{3(aq)}$ $= (\frac{5,2766}{1.034,2089}) \times 100\% \times 1.034,2089 \frac{kg}{jam} = 5,2766 \frac{kg}{jam}$
  3) $H_2O_{(l)}$ $= (\frac{770,3801}{1.034,2089}) \times 100\% \times 1.034,2089 \frac{kg}{jam} = 770,3801 \frac{kg}{jam}$

Tabel A.27 Neraca Massa *Mixing Tank 1*

Komponen	Masuk				Keluar	
	Aliran 15		Aliran 16		Aliran 17	
	Massa (kg/jam)	%	Massa (kg/jam)	%	Massa (kg/jam)	%
KOH	258,5522	98%			258,5522	25%
K_2CO_3	5,2766	2%			5,2766	0,5%
H_2O			770,3801	100%	770,3801	74,5%
Sub total	**263,8288**	**100%**	**770,3801**	**100%**	**1.034,2089**	**100%**
Total	**1.034,2089**				**1.034,2089**	

7. *Netralizer Reactor*

Fungsi : Mereaksikan Asam lemak dengan Kalium hidroksida untuk menghasilkan sabun cair.



Kondisi Operasi:

- Temperatur : 80 °C
- Tekanan : 1 atm

Aliran 14 : *Bottom product deodorizer* (Asam lemak)

Aliran 18 : Kalium hidroksida 25%

Aliran 19 : Sabun cair

Laju alir *Palm fatty acid distillate* dari *deodorizer* = 1.279,6562 kg/jam.

Reaksi 1

- $C_{12}H_{24}O_2$ = 0,12%

  Konversi reaksi = 99%

	$C_{12}H_{24}O_{2\,(l)}$	+ $KOH_{(aq)}$	→ $C_{12}H_{23}O_2K_{(l)}$	+ $H_2O_{(l)}$
M	: 0,00781	0,00781		
B	: 0,00777	0,00777	0,00777	0,00777
S	: 0,00004	0,00004	0,00777	0,00777

Reaksi 2

- $C_{14}H_{28}O_2$ = 0,90%

  Konversi reaksi = 99%

	$C_{14}H_{28}O_{2\,(l)}$	+ $KOH_{(aq)}$	→ $C_{14}H_{27}O_2K_{(l)}$	+ $H_2O_{(l)}$
M	: 0,05071	0,05071		
B	: 0,05045	0,05045	0,05045	0,05045
S	: 0,00025	0,00025	0,05045	0,05045

Reaksi 3

- $C_{16}H_{32}O_2$ = 38,59%

  Konversi reaksi = 99%

	$C_{16}H_{32}O_{2\,(l)}$	+ $KOH_{(aq)}$	→ $C_{16}H_{31}O_2K_{(l)}$	+ $H_2O_{(l)}$
M	: 1,92912	1,92912		
B	: 1,91935	1,91935	1,91935	1,91935
S	: 0,00978	0,00978	1,91935	1,91935

Reaksi 4

- $C_{18}H_{36}O_2$ = 3,79%

  Konversi reaksi = 99%

	$C_{18}H_{36}O_{2\,(l)}$	+ $KOH_{(aq)}$	→ $C_{18}H_{35}O_2K_{(l)}$	+ $H_2O_{(l)}$
M	: 0,17067	0,17067		
B	: 0,16982	0,16982	0,16982	0,16982
S	: 0,00086	0,00086	0,16982	0,16982

Reaksi 5

- $C_{18}H_{34}O_2$ = 31,06%

  Konversi reaksi = 99%

	$C_{18}H_{34}O_{2\,(l)}$ +	$KOH_{(aq)}$ →	$C_{18}H_{33}O_2K_{(l)}$ +	$H_2O_{(l)}$
M	: 1,40946	1,40946		
B	: 1,40239	1,40239	1,40239	1,40239
S	: 0,00707	0,00707	1,40239	1,40239

Reaksi 6

- $C_{18}H_{32}O_2$ = 8,61%

  Konversi reaksi = 99%

	$C_{18}H_{32}O_{2\,(l)}$ +	$KOH_{(aq)}$ →	$C_{18}H_{31}O_2K_{(l)}$ +	$H_2O_{(l)}$
M	: 0,39364	0,39364		
B	: 0,39167	0,39167	0,39167	0,39167
S	: 0,00197	0,00197	0,39167	0,39167

Reaksi 7

- $C_{57}H_{104}O_6$ = 15%

  Konversi reaksi = 62%

	$C_{57}H_{104}O_{6\,(l)}$ +	$3KOH_{(aq)}$ →	$3C_{18}H_{31}O_2K_{(l)}$ +	$3H_8O_{3(l)}$
M	: 0,21853	0,65559		
B	: 0,13561	0,40684	0,40684	0,13561
S	: 0,08292	0,24875	0,40684	0,13561

Neraca massa total :

Aliran 14 + Aliran 18 = Aliran 19

$1.279,6562\,\frac{kg}{jam} + 1.034,2809\,\frac{kg}{jam} = 2.313,8652\,\frac{kg}{jam}$

Neraca massa komponen :

- **Input**

- Aliran 14

1) $H_2O_{(l)}$ $= 0,0002\% \times 1.279,6562 \frac{kg}{jam} = 0,0027 \frac{kg}{jam}$

2) $C_6H_{10}O_{(l)}$ $= 0,0100\% \times 1.279,6562 \frac{kg}{jam} = 0,1283 \frac{kg}{jam}$

3) $C_7H_{14}O_{(l)}$ $= 0,0062\% \times 1.279,6562 \frac{kg}{jam} = 0,0795 \frac{kg}{jam}$

4) $C_8H_{16}O_{(l)}$ $= 0,0282\% \times 1.279,6562 \frac{kg}{jam} = 0,3603 \frac{kg}{jam}$

5) $C_9H_{18}O_{(l)}$ $= 0,0001\% \times 1.279,6562 \frac{kg}{jam} = 0,0007 \frac{kg}{jam}$

6) $C_{29}H_{50}O_{2(l)}$ $= 0,5236\% \times 1.279,6562 \frac{kg}{jam} = 6,7004 \frac{kg}{jam}$

7) $C_{12}H_{24}O_{2(l)}$ $= 0,1220\% \times 1.279,6562 \frac{kg}{jam} = 1,5613 \frac{kg}{jam}$

8) $C_{14}H_{28}O_{2(l)}$ $= 0,9035\% \times 1.279,6562 \frac{kg}{jam} = 11,5616 \frac{kg}{jam}$

9) $C_{16}H_{32}O_{2(l)}$ $= 38,5928\% \times 1.279,6562 \frac{kg}{jam} = 493,8555 \frac{kg}{jam}$

10) $C_{18}H_{34}O_{2(l)}$ $= 31,0606\% \times 1.279,6562 \frac{kg}{jam} = 397,4683 \frac{kg}{jam}$

11) $C_{27}H_{46}O_{(l)}$ $= 0,8366\% \times 1.279,6562 \frac{kg}{jam} = 10,7062 \frac{kg}{jam}$

12) $C_{18}H_{32}O_{2(l)}$ $= 8,6132\% \times 1.279,6562 \frac{kg}{jam} = 110,2191 \frac{kg}{jam}$

13) $C_{18}H_{36}O_{2(l)}$ $= 3,7878\% \times 1.279,6562 \frac{kg}{jam} = 48,4713 \frac{kg}{jam}$

14) $C_{30}H_{50(l)}$ $= 0,4189\% \times 1.279,6562 \frac{kg}{jam} = 5,3604 \frac{kg}{jam}$

15) $C_{57}H_{104}O_{6(l)}$ $= 15,0963\% \times 1.279,6562 \frac{kg}{jam} = 193,1806 \frac{kg}{jam}$

- Aliran 18

1) $KOH_{(aq)}$ $= 25\% \times 1.034,2089 \frac{kg}{jam} = 258,5522 \frac{kg}{jam}$

2) $K_2CO_{3(aq)}$ $= 0,51\% \times 1.034,2089 \frac{kg}{jam} = 5,2766 \frac{kg}{jam}$

3) $H_2O_{(aq)}$ $= 74,49\% \times 1.034,2089 \frac{kg}{jam} = 770,3801 \frac{kg}{jam}$

- **Output**

- Aliran 19

1) $H_2O_{(l)}$ = (0,0027 + 770,3801 + 70,9460) $\frac{kg}{jam}$ = 841,3288 $\frac{kg}{jam}$
2) $C_6H_{10}O_{(l)}$ = 0,1283 $\frac{kg}{jam}$
3) $C_7H_{14}O_{(l)}$ = 0,0795 $\frac{kg}{jam}$
4) $C_8H_{16}O_{(l)}$ = 0,3603 $\frac{kg}{jam}$
5) $C_9H_{18}O_{(l)}$ = 0,0007 $\frac{kg}{jam}$
6) $C_{29}H_{50}O_{2(l)}$ = 6,7004 $\frac{kg}{jam}$
7) $C_{12}H_{24}O_{2(l)}$ = 0,0078 $\frac{kg}{jam}$
8) $C_{14}H_{28}O_{2(l)}$ = 0,0580 $\frac{kg}{jam}$
9) $C_{16}H_{32}O_{2(l)}$ = 2,5026 $\frac{kg}{jam}$
10) $C_{18}H_{34}O_{2(l)}$ = 1,9939 $\frac{kg}{jam}$
11) $C_{27}H_{46}O_{(l)}$ = 10,7062 $\frac{kg}{jam}$
12) $C_{18}H_{32}O_{2(l)}$ = 0,5529 $\frac{kg}{jam}$
13) $C_{18}H_{36}O_{2(l)}$ = 0,2432 $\frac{kg}{jam}$
14) $C_{30}H_{50(l)}$ = 5,3604 $\frac{kg}{jam}$
15) $C_{57}H_{104}O_{6(l)}$ = 73,2992 $\frac{kg}{jam}$
16) $KOH_{(l)}$ = 15,0485 $\frac{kg}{jam}$
17) $K_2CO_{3(l)}$ = 5,2766 $\frac{kg}{jam}$
18) $C_{12}H_{23}O_2K_{(l)}$ = 1,8487 $\frac{kg}{jam}$
19) $C_{14}H_{27}O_2K_{(l)}$ = 13,4209 $\frac{kg}{jam}$
20) $C_{16}H_{31}O_2K_{(l)}$ = 564,2880 $\frac{kg}{jam}$
21) $C_{18}H_{35}O_2K_{(l)}$ = 54,6812 $\frac{kg}{jam}$
22) $C_{18}H_{33}O_2K_{(l)}$ = 578,9533 $\frac{kg}{jam}$
23) $C_{18}H_{31}O_2K_{(l)}$ = 124,5495 $\frac{kg}{jam}$
24) $C_3H_8O_{3(l)}$ = 12,4764 $\frac{kg}{jam}$

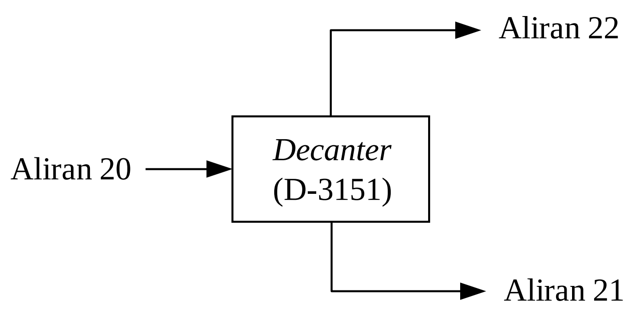
Tabel A.28 Neraca Massa *Netralizer Reactor*

Komponen	Masuk				Keluar	
	Aliran 14		Aliran 18		Aliran 19	
	Massa (kg/jam)	%	Massa (kg/jam)	%	Massa (kg/jam)	%
H_2O	0,0027	0,0002%	770,3801	74,5%	841,3288	36,3603%
$C_6H_{10}O$	0,1283	0,0100%			0,1283	0,0055%
$C_7H_{14}O$	0,0795	0,0062%			0,0795	0,0034%
$C_8H_{16}O$	0,3603	0,0282%			0,3603	0,0156%
$C_9H_{18}O$	0,0007	0,0001%			0,0007	0,00003%
$C_{29}H_{50}O_2$	6,7004	0,5236%			6,7004	0,2896%
$C_{12}H_{24}O_2$	1,5613	0,1220%			0,0078	0,0003%
$C_{14}H_{28}O_2$	11,5616	0,9035%			0,0580	0,0025%
$C_{16}H_{32}O_2$	493,8555	38,5928%			2,5026	0,1082%

$C_{18}H_{34}O_2$	397,4683	31,0606%			1,9939	0,0862%
$C_{27}H_{46}O$	10,7062	0,8366%			10,7062	0,4627%
$C_{18}H_{32}O_2$	110,2191	8,6132%			0,5529	0,0239%
$C_{18}H_{36}O_2$	48,4713	3,7878%			0,2432	0,0105%
$C_{30}H_{50}$	5,3604	0,4189%			5,3604	0,2317%
$C_{57}H_{104}O_6$	193,1806	15,0963%			73,2992	3,1678%
KOH			258,5522	25,0%	15,0485	0,6504%
K_2CO_3			5,2766	0,5%	5,2766	0,2280%
$C_{12}H_{23}O_2K$					1,8487	0,0799%
$C_{14}H_{27}O_2K$					13,4209	0,5800%
$C_{16}H_{31}O_2K$					564,2880	24,3872%
$C_{18}H_{35}O_2K$					54,6812	2,3632%
$C_{18}H_{33}O_2K$					578,9533	25,0210%
$C_{18}H_{31}O_2K$					124,5495	5,3827%
$C_3H_8O_3$					12,4764	0,5392%
Sub total	**1.279,6562**	**100%**	**1034,2089**	**100%**	**2.313,8652**	**100%**
Total	**2.313,8652**				**2.313,8652**	

8. *Decanter*

Fungsi : Memisahkan Triolein sisa dengan Sabun cair berdasarkan perbedaan densitas.



Kondisi Operasi:

- Temperatur : 30 °C
- Tekanan : 1 atm
- Efisiensi Pemisahan : 98%

Aliran 20 : Produk keluaran *Netralizer Reactor*

Aliran 21 : *Heavy phase*

Aliran 22 : *Light phase*

Proses pemisahan dilakukan berdasarkan densitas dari $C_{57}H_{104}O_6$, dan Sabun cair.

Densitas $C_{57}H_{104}O_6$ = 866,8611 kg/m^3

Densitas Sabun cair = 1015,0453 kg/m^3

Berdasarkan perbedaan densitas tersebut maka,

Light phase = $C_{57}H_{104}O_6$

Heavy phase = Sabun cair

Light phase akan terpisah 98% dari komponen sabun karena perbedaan densitas tersebut. Kemudian berdasarkan (B. Bianchi et al, 2013) 2% dari umpan akan terbawa sebagai residu dalam *light phase*.

Neraca massa total :

Aliran 20 = Aliran 21 + Aliran 22

$2.313,8652 \frac{kg}{jam}$ = Aliran 21 + Aliran 22

Neraca massa komponen :

- **Input**

- Aliran 20

1) $H_2O_{(l)}$ = $36,3603\% \times 2.313,8652 \frac{kg}{jam} = 841,3288 \frac{kg}{jam}$
2) $C_6H_{10}O_{(l)}$ = $0,0055\% \times 2.313,8652 \frac{kg}{jam} = 0,1283 \frac{kg}{jam}$
3) $C_7H_{14}O_{(l)}$ = $0,0034\% \times 2.313,8652 \frac{kg}{jam} = 0,0795 \frac{kg}{jam}$
4) $C_8H_{16}O_{(l)}$ = $0,0156\% \times 2.313,8652 \frac{kg}{jam} = 0,3603 \frac{kg}{jam}$
5) $C_9H_{18}O_{(l)}$ = $0,000003\% \times 2.313,8652 \frac{kg}{jam} = 0,0007 \frac{kg}{jam}$
6) $C_{29}H_{50}O_{2(l)}$ = $0,2896\% \times 2.313,8652 \frac{kg}{jam} = 6,7004 \frac{kg}{jam}$
7) $C_{12}H_{24}O_{2(l)}$ = $0,0003\% \times 2.313,8652 \frac{kg}{jam} = 0,0078 \frac{kg}{jam}$
8) $C_{14}H_{28}O_{2(l)}$ = $0,0025\% \times 2.313,8652 \frac{kg}{jam} = 0,0580 \frac{kg}{jam}$
9) $C_{16}H_{32}O_{2(l)}$ = $0,1082\% \times 2.313,8652 \frac{kg}{jam} = 2,5026 \frac{kg}{jam}$
10) $C_{18}H_{34}O_{2(l)}$ = $0,0862\% \times 2.313,8652 \frac{kg}{jam} = 1,9939 \frac{kg}{jam}$

11) $C_{27}H_{46}O_{(l)}$ $= 0{,}4627\% \times 2.313{,}8652 \frac{kg}{jam} = 10{,}7062 \frac{kg}{jam}$

12) $C_{18}H_{32}O_{2(l)}$ $= 0{,}0239\% \times 2.313{,}8652 \frac{kg}{jam} = 0{,}5529 \frac{kg}{jam}$

13) $C_{18}H_{36}O_{2(l)}$ $= 0{,}0105\% \times 2.313{,}8652 \frac{kg}{jam} = 0{,}2432 \frac{kg}{jam}$

14) $C_{30}H_{50(l)}$ $= 0{,}2317\% \times 2.313{,}8652 \frac{kg}{jam} = 5{,}3604 \frac{kg}{jam}$

15) $C_{57}H_{104}O_{6(l)}$ $= 3{,}1678\% \times 2.313{,}8652 \frac{kg}{jam} = 73{,}2992 \frac{kg}{jam}$

16) $KOH_{(aq)}$ $= 0{,}6504\% \times 2.313{,}8652 \frac{kg}{jam} = 15{,}0485 \frac{kg}{jam}$

17) $K_2CO_{3(aq)}$ $= 0{,}2280\% \times 2.313{,}8652 \frac{kg}{jam} = 5{,}2766 \frac{kg}{jam}$

18) $C_{12}H_{23}O_2K_{(l)}$ $= 0{,}0799\% \times 2.313{,}8652 \frac{kg}{jam} = 1{,}8487 \frac{kg}{jam}$

19) $C_{14}H_{27}O_2K_{(l)}$ $= 0{,}5800\% \times 2.313{,}8652 \frac{kg}{jam} = 13{,}4209 \frac{kg}{jam}$

20) $C_{16}H_{31}O_2K_{(l)}$ $= 24{,}3872\% \times 2.313{,}8652 \frac{kg}{jam} = 564{,}2880 \frac{kg}{jam}$

21) $C_{18}H_{35}O_2K_{(l)}$ $= 2{,}3632\% \times 2.313{,}8652 \frac{kg}{jam} = 54{,}6812 \frac{kg}{jam}$

22) $C_{18}H_{33}O_2K_{(l)}$ $= 25{,}0210\% \times 2.313{,}8652 \frac{kg}{jam} = 578{,}9533 \frac{kg}{jam}$

23) $C_{18}H_{31}O_2K_{(l)}$ $= 5{,}3827\% \times 2.313{,}8652 \frac{kg}{jam} = 124{,}5495 \frac{kg}{jam}$

24) $C_3H_8O_{3(l)}$ $=0{,}5392\% \times 2.313{,}8652 \frac{kg}{jam} = 12{,}4764 \frac{kg}{jam}$

- **Output**

- Aliran 21

1) $H_2O_{(l)}$ $= 2\% \times 841{,}3288 \frac{kg}{jam} = 16{,}8266 \frac{kg}{jam}$

2) $C_6H_{10}O_{(l)}$ $= 2\% \times 0{,}1283 \frac{kg}{jam} = 0{,}0026 \frac{kg}{jam}$

3) $C_7H_{14}O_{(l)}$ $= 2\% \times 0{,}0795 \frac{kg}{jam} = 0{,}0016 \frac{kg}{jam}$

4) $C_8H_{16}O_{(l)}$ $= 2\% \times 0{,}3603 \frac{kg}{jam} = 0{,}0072 \frac{kg}{jam}$

5) $C_9H_{18}O_{(l)}$ $= 2\% \times 0{,}0007 \frac{kg}{jam} = 0{,}00001 \frac{kg}{jam}$

6) $C_{29}H_{50}O_{2(l)}$ $= 2\% \times 6{,}7004 \frac{kg}{jam} = 0{,}1340 \frac{kg}{jam}$

7) $C_{12}H_{24}O_{2(l)}$ = 2% × 0,0078 $\frac{kg}{jam}$ = 0,0002 $\frac{kg}{jam}$

8) $C_{14}H_{28}O_{2(l)}$ = 2% × 0,0580 $\frac{kg}{jam}$ = 0,0012 $\frac{kg}{jam}$

9) $C_{16}H_{32}O_{2(l)}$ = 2% × 2,5026 $\frac{kg}{jam}$ = 0,0501 $\frac{kg}{jam}$

10) $C_{18}H_{34}O_{2(l)}$ = 2% × 1,9939 $\frac{kg}{jam}$ = 0,0399 $\frac{kg}{jam}$

11) $C_{27}H_{46}O_{(l)}$ = 2% × 10,7062 $\frac{kg}{jam}$ = 0,2141 $\frac{kg}{jam}$

12) $C_{18}H_{32}O_{2(l)}$ = 2% × 0,5529 $\frac{kg}{jam}$ = 0,0111 $\frac{kg}{jam}$

13) $C_{18}H_{36}O_{2(l)}$ = 2% × 0,2432 $\frac{kg}{jam}$ = 0,0049 $\frac{kg}{jam}$

14) $C_{30}H_{50(l)}$ = 2% × 5,3604 $\frac{kg}{jam}$ = 0,1072 $\frac{kg}{jam}$

15) $C_{57}H_{104}O_{6(l)}$ = 98% × 73,2992 $\frac{kg}{jam}$ = 71,8332 $\frac{kg}{jam}$

16) $KOH_{(l)}$ = 2% × 15,0485 $\frac{kg}{jam}$ = 0,3010 $\frac{kg}{jam}$

17) $K_2CO_{3(l)}$ = 2% × 5,2766 $\frac{kg}{jam}$ = 0,1055 $\frac{kg}{jam}$

18) $C_{12}H_{23}O_2K_{(l)}$ = 2% × 1,8487 $\frac{kg}{jam}$ = 0,0370 $\frac{kg}{jam}$

19) $C_{14}H_{27}O_2K_{(l)}$ = 2% × 13,4209 $\frac{kg}{jam}$ = 0,2684 $\frac{kg}{jam}$

20) $C_{16}H_{31}O_2K_{(l)}$ = 2% × 564,2880 $\frac{kg}{jam}$ = 11,2858 $\frac{kg}{jam}$

21) $C_{18}H_{35}O_2K_{(l)}$ = 2% × 54,6812 $\frac{kg}{jam}$ = 1,0936 $\frac{kg}{jam}$

22) $C_{18}H_{33}O_2K_{(l)}$ = 2% × 578,9533 $\frac{kg}{jam}$ = 11,5791 $\frac{kg}{jam}$

23) $C_{18}H_{31}O_2K_{(l)}$ = 2% × 124,5495 $\frac{kg}{jam}$ = 2,4910 $\frac{kg}{jam}$

24) $C_3H_8O_{3(l)}$ =2% × 12,4764 $\frac{kg}{jam}$ = 0,2495 $\frac{kg}{jam}$

- Aliran 22

1) $H_2O_{(l)}$ = (100% - 2 %) × 841,3288 $\frac{kg}{jam}$ = 824,5022 $\frac{kg}{jam}$

2) $C_6H_{10}O_{(l)}$ = (100% - 2%) × 0,1283 $\frac{kg}{jam}$ = 0,1257 $\frac{kg}{jam}$

3) $C_7H_{14}O_{(l)}$ = (100% - 2%) × 0,0795 $\frac{kg}{jam}$ = 0,0779 $\frac{kg}{jam}$

4) $C_8H_{16}O_{(l)}$ = (100% - 2%) × 0,3603 $\frac{kg}{jam}$ = 0,3531 $\frac{kg}{jam}$

5) $C_9H_{18}O_{(l)}$ = (100% - 2%) × 0,0007 $\frac{kg}{jam}$ = 0,0007 $\frac{kg}{jam}$

6) $C_{29}H_{50}O_{2(l)}$ = (100% - 2%) × 6,7004 $\frac{kg}{jam}$ = 6,5664 $\frac{kg}{jam}$

7) $C_{12}H_{24}O_{2(l)}$ = (100% - 2%) × 0,0078 $\frac{kg}{jam}$ = 0,0077 $\frac{kg}{jam}$

8) $C_{14}H_{28}O_{2(l)}$ = (100% - 2%) × 0,0580 $\frac{kg}{jam}$ = 0,0568 $\frac{kg}{jam}$

9) $C_{16}H_{32}O_{2(l)}$ = (100% - 2%) × 2,5026 $\frac{kg}{jam}$ = 2,4526 $\frac{kg}{jam}$

10) $C_{18}H_{34}O_{2(l)}$ = (100% - 2%) × 1,9939 $\frac{kg}{jam}$ = 1,9540 $\frac{kg}{jam}$

11) $C_{27}H_{46}O_{(l)}$ = (100% - 2%) × 10,7062 $\frac{kg}{jam}$ = 10,4920 $\frac{kg}{jam}$

12) $C_{18}H_{32}O_{2(l)}$ = (100% - 2%) × 0,5529 $\frac{kg}{jam}$ = 0,5419 $\frac{kg}{jam}$

13) $C_{18}H_{36}O_{2(l)}$ = (100% - 2%) × 0,2432 $\frac{kg}{jam}$ = 0,2383 $\frac{kg}{jam}$

14) $C_{30}H_{50(l)}$ = (100% - 2%) × 5,3604 $\frac{kg}{jam}$ = 5,2523 $\frac{kg}{jam}$

15) $C_{57}H_{104}O_{6(l)}$ = (100% - 98%) × 73,2992 $\frac{kg}{jam}$ = 1,4660 $\frac{kg}{jam}$

16) $KOH_{(l)}$ = (100% - 2%) × 15,0485 $\frac{kg}{jam}$ = 14,7476 $\frac{kg}{jam}$

17) $K_2CO_{3(l)}$ = (100% - 2%) × 5,2766 $\frac{kg}{jam}$ = 5,1710 $\frac{kg}{jam}$

18) $C_{12}H_{23}O_2K_{(l)}$ = (100% - 2%) × 1,8487 $\frac{kg}{jam}$ = 1,8117 $\frac{kg}{jam}$

19) $C_{14}H_{27}O_2K_{(l)}$ = (100% - 2%) × 13,4209 $\frac{kg}{jam}$ = 13,1525 $\frac{kg}{jam}$

20) $C_{16}H_{31}O_2K_{(l)}$ = (100% - 2%) × 564,2880 $\frac{kg}{jam}$ = 553,0023 $\frac{kg}{jam}$

21) $C_{18}H_{35}O_2K_{(l)}$ = (100% - 2%) × 54,6812 $\frac{kg}{jam}$ = 53,5875 $\frac{kg}{jam}$

22) $C_{18}H_{33}O_2K_{(l)}$ = (100% - 2%) × 578,9533 $\frac{kg}{jam}$ = 567,3742 $\frac{kg}{jam}$

23) $C_{18}H_{31}O_2K_{(l)}$ = (100% - 2%) × 124,5495 $\frac{kg}{jam}$ = 122,0585 $\frac{kg}{jam}$

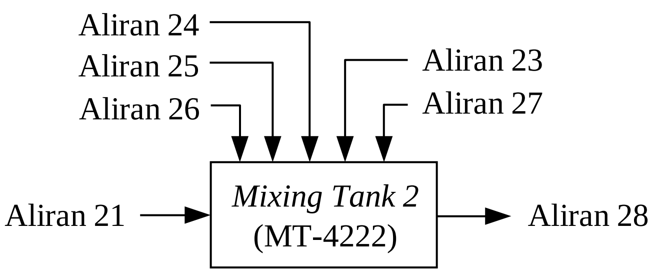
24) $C_3H_8O_{3(l)}$ =(100% - 2%) × 12,4764 $\frac{kg}{jam}$ = 12,2268 $\frac{kg}{jam}$

Tabel A.29 Neraca Massa *Decanter*

Komponen	Masuk		Keluar			
	Aliran 20		Aliran 22		Aliran 21	
	Massa (kg/jam)	%	Massa (kg/jam)	%	Massa (kg/jam)	%
H_2O	841,3288	36,3603%	16,8266	14,426%	824,5022	37,5248%
$C_6H_{10}O$	0,1283	0,0055%	0,0026	0,002%	0,1257	0,0057%
$C_7H_{14}O$	0,0795	0,0034%	0,0016	0,001%	0,0779	0,0035%
$C_8H_{16}O$	0,3603	0,0156%	0,0072	0,006%	0,3531	0,0161%
$C_9H_{18}O$	0,0007	0,00003%	0,00001	0,00001%	0,0007	0,00003%
$C_{29}H_{50}O_2$	6,7004	0,2896%	0,1340	0,115%	6,5664	0,2989%
$C_{12}H_{24}O_2$	0,0078	0,0003%	0,0002	0,0001%	0,0077	0,0003%
$C_{14}H_{28}O_2$	0,0580	0,0025%	0,0012	0,001%	0,0568	0,0026%
$C_{16}H_{32}O_2$	2,5026	0,1082%	0,0501	0,043%	2,4526	0,1116%
$C_{18}H_{34}O_2$	1,9939	0,0862%	0,0399	0,034%	1,9540	0,0889%
$C_{27}H_{46}O$	10,7062	0,4627%	0,2141	0,184%	10,4920	0,4775%
$C_{18}H_{32}O_2$	0,5529	0,0239%	0,0111	0,009%	0,5419	0,0247%
$C_{18}H_{36}O_2$	0,2432	0,0105%	0,0049	0,004%	0,2383	0,0108%
$C_{30}H_{50}$	5,3604	0,2317%	0,1072	0,092%	5,2532	0,2391%
$C_{57}H_{104}O_6$	73,2992	3,1678%	71,8332	61,583%	1,4660	0,0667%
KOH	15,0485	0,6504%	0,3010	0,258%	14,7476	0,6712%
K_2CO_3	5,2766	0,2280%	0,1055	0,090%	5,1710	0,2353%
$C_{12}H_{23}O_2K$	1,8487	0,0799%	0,0370	0,032%	1,8117	0,0825%
$C_{14}H_{27}O_2K$	13,4209	0,5800%	0,2684	0,230%	13,1525	0,5986%
$C_{16}H_{31}O_2K$	564,2880	24,3872%	11,2858	9,675%	553,0023	25,1683%
$C_{18}H_{35}O_2K$	54,6812	2,3632%	1,0936	0,938%	53,5875	2,4389%
$C_{18}H_{33}O_2K$	578,9533	25,0210%	11,5791	9,927%	567,3742	25,8224%
$C_{18}H_{31}O_2K$	124,5495	5,3827%	2,4910	2,136%	122,0585	5,5551%
$C_3H_8O_3$	12,4764	0,5392%	0,2495	0,214%	12,2268	0,5565%
Sub total	**2.313,8652**	**100%**	**116,6445**	**100%**	**2.197,2207**	**100%**
Total	**2.313,8652**		**2.313,8652**			

9. Mixing Tank 2

Fungsi : Mencampurkan produk keluaran *Decanter* dengan bahan aditif.



Kondisi Operasi:

- Temperatur : 30 °C
- Tekanan : 1 atm

Aliran 21 : Produk hasil pemisahan *Decanter*
Aliran 23 : *Ethylene diamine tetra acetic acid*
Aliran 24 : *Triclocarban*
Aliran 25 : *Sunset yellow FCF*
Aliran 26 : *Glycerol*
Aliran 27 : *Cocoamidopropyl betaine*
Aliran 28 : Produk hasil pencampuran *Mixing tank 2*

Berdasarkan (*Encyclopedia of Chemical Technology, Kirk-Othmer, 2007* Halaman 19), jumlah *Ethylene diamine tetra acetic acid* yang digunakan adalah 0,1% - 0,2% **(0,2%)** dari jumlah total sabun.

Kemudian Berdasarkan (*Soap Manufacturing Technology, Luis Spitz* Halaman 68), jumlah *Triclocarban* yang digunakan adalah 0,25% - 1,5% **(1%)** dari jumlah total sabun.

Kemudian Berdasarkan (*Encyclopedia of Chemical Technology, Kirk-Othmer, 2007* Halaman 18), jumlah *Glycerol* yang digunakan adalah 5% - 10% **(10%)** dari jumlah total sabun.

Kemudian Berdasarkan (*Soap Manufacturing Technology, Luis Spitz* Halaman 62), jumlah zat pewarna yang digunakan adalah 1% - 2% **(1%)** dari jumlah total sabun.

Kemudian Berdasarkan (*Soap Manufacturing Technology, Luis Spitz* Halaman 119), jumlah *Cocoamidopropyl betaine* yang digunakan adalah dibawah 5% **(2,5%)** dari jumlah total sabun.

Neraca massa total :

Aliran 21 + Aliran 23 + Aliran 24 + Aliran 25 + Aliran 26 + Aliran 27 = Aliran 28

$$2.197,2207\,\frac{kg}{jam} + 4,3944\,\frac{kg}{jam} + 21,9722\,\frac{kg}{jam} + 21,9722\,\frac{kg}{jam} + 219,7221\,\frac{kg}{jam} +$$

$54{,}9305\frac{kg}{jam} = 2.520{,}2121\frac{kg}{jam}$

Neraca massa komponen :

- **Input**

- Aliran 21
  1) $H_2O_{(l)}$ = $37{,}5248\% \times 2.197{,}2207\frac{kg}{jam} = 824{,}5022\frac{kg}{jam}$
  2) $C_6H_{10}O_{(l)}$ = $0{,}0057\% \times 2.197{,}2207\frac{kg}{jam} = 0{,}1257\frac{kg}{jam}$
  3) $C_7H_{14}O_{(l)}$ = $0{,}0035\% \times 2.197{,}2207\frac{kg}{jam} = 0{,}0779\frac{kg}{jam}$
  4) $C_8H_{16}O_{(l)}$ = $0{,}0161\% \times 2.197{,}2207\frac{kg}{jam} = 0{,}3531\frac{kg}{jam}$
  5) $C_9H_{18}O_{(l)}$ = $0{,}00003\% \times 2.197{,}2207\frac{kg}{jam} = 0{,}0007\frac{kg}{jam}$
  6) $C_{29}H_{50}O_{2(l)}$ = $0{,}2989\% \times 2.197{,}2207\frac{kg}{jam} = 6{,}5664\frac{kg}{jam}$
  7) $C_{12}H_{24}O_{2(l)}$ = $0{,}0003\% \times 2.197{,}2207\frac{kg}{jam} = 0{,}0077\frac{kg}{jam}$
  8) $C_{14}H_{28}O_{2(l)}$ = $0{,}0026\% \times 2.197{,}2207\frac{kg}{jam} = 0{,}0568\frac{kg}{jam}$
  9) $C_{16}H_{32}O_{2(l)}$ = $0{,}1116\% \times 2.197{,}2207\frac{kg}{jam} = 2{,}4526\frac{kg}{jam}$
  10) $C_{18}H_{34}O_{2(l)}$ = $0{,}0889\% \times 2.197{,}2207\frac{kg}{jam} = 1{,}9540\frac{kg}{jam}$
  11) $C_{27}H_{46}O_{(l)}$ = $0{,}4775\% \times 2.197{,}2207\frac{kg}{jam} = 10{,}4920\frac{kg}{jam}$
  12) $C_{18}H_{32}O_{2(l)}$ = $0{,}0247\% \times 2.197{,}2207\frac{kg}{jam} = 0{,}5419\frac{kg}{jam}$
  13) $C_{18}H_{36}O_{2(l)}$ = $0{,}0108\% \times 2.197{,}2207\frac{kg}{jam} = 0{,}2383\frac{kg}{jam}$
  14) $C_{30}H_{50(l)}$ = $0{,}2391\% \times 2.197{,}2207\frac{kg}{jam} = 2{,}2532\frac{kg}{jam}$
  15) $C_{57}H_{104}O_{6(l)}$ = $0{,}0667\% \times 2.197{,}2207\frac{kg}{jam} = 1{,}4660\frac{kg}{jam}$
  16) $KOH_{(l)}$ = $0{,}6712\% \times 2.197{,}2207\frac{kg}{jam} = 14{,}7476\frac{kg}{jam}$
  17) $K_2CO_{3(l)}$ = $0{,}2353\% \times 2.197{,}2207\frac{kg}{jam} = 5{,}1710\frac{kg}{jam}$
  18) $C_{12}H_{23}O_2K_{(l)}$ = $0{,}0825\% \times 2.197{,}2207\frac{kg}{jam} = 1{,}8117\frac{kg}{jam}$
  19) $C_{14}H_{27}O_2K_{(l)}$ = $0{,}5986\% \times 2.197{,}2207\frac{kg}{jam} = 13{,}1525\frac{kg}{jam}$

20) $C_{16}H_{31}O_2K_{(l)}$ = 25,1683% × 1.184,6327 $\frac{kg}{jam}$ = 553,0023 $\frac{kg}{jam}$

21) $C_{18}H_{35}O_2K_{(l)}$ = 2,4389% × 2.197,2207 $\frac{kg}{jam}$ = 53,5875 $\frac{kg}{jam}$

22) $C_{18}H_{33}O_2K_{(l)}$ = 25,8224% × 2.197,2207 $\frac{kg}{jam}$ = 567,3742 $\frac{kg}{jam}$

23) $C_{18}H_{31}O_2K_{(l)}$ = 5,5551% × 2.197,2207 $\frac{kg}{jam}$ = 122,0585 $\frac{kg}{jam}$

24) $C_3H_8O_{3(l)}$ =0,5565% × 2.197,2207 $\frac{kg}{jam}$ = 12,2268 $\frac{kg}{jam}$

- Aliran 23

  $C_{10}H_{16}N_2O_8$ yang digunakan adalah dengan konsentrasi 99%

  $C_{10}H_{16}N_2O_8$ yang diperlukan adalah :

  $C_{10}H_{16}N_2O_8$ = 0,2% × Total sabun

  = 0,2% × 2.197,2207 $\frac{kg}{jam}$

  = 4,3944 $\frac{kg}{jam}$

  $C_{10}H_{16}N_2O_{8(s)}$ = 99% × 4,3944 $\frac{kg}{jam}$ = 4,3505 $\frac{kg}{jam}$

  $H_2O_{(l)}$ = 1% × 4,3944 $\frac{kg}{jam}$ = 0,0439 $\frac{kg}{jam}$

- Aliran 24

  $C_{13}H_9Cl_3N_2O$ yang digunakan adalah dengan konsentrasi 98%

  $C_{13}H_9Cl_3N_2O$ yang diperlukan adalah :

  $C_{13}H_9Cl_3N_2O$ = 1% × Total sabun

  = 1% × 2.197,2207 $\frac{kg}{jam}$

  = 21,9722 $\frac{kg}{jam}$

  $C_{13}H_9Cl_3N_2O_{(s)}$ = 98% × 21,9722 $\frac{kg}{jam}$ = 21,5328 $\frac{kg}{jam}$

  $H_2O_{(l)}$ = 2% × 21,9722 $\frac{kg}{jam}$ = 0,4394 $\frac{kg}{jam}$

- Aliran 25

  $C_{16}H_{10}N_2Na_2O_7S_2$ yang digunakan adalah dengan konsentrasi 100%

  $C_{16}H_{10}N_2Na_2O_7S_2$ yang diperlukan adalah :

$C_{16}H_{10}N_2Na_2O_7S_2$ = 1% × Total sabun

= 1% × 2.197,2207 $\frac{kg}{jam}$

= 21,9722 $\frac{kg}{jam}$

$C_{16}H_{10}N_2Na_2O_7S_{2(s)}$ =100% × 21,9722 $\frac{kg}{jam}$ = 21,9722 $\frac{kg}{jam}$

- Aliran 26

$C_3H_8O_3$ yang digunakan adalah dengan konsentrasi 99,5%

$C_3H_8O_3$ yang diperlukan adalah :

$C_3H_8O_3$ = 10% × Total sabun

= 10% × 2.197,2207 $\frac{kg}{jam}$

= 219,7221 $\frac{kg}{jam}$

$C_3H_8O_{3(l)}$ = 99,5% × 219,7221 $\frac{kg}{jam}$ = 218,6235 $\frac{kg}{jam}$

$H_2O_{(l)}$ = 0,5% × 219,7221 $\frac{kg}{jam}$ = 1,0986 $\frac{kg}{jam}$

- Aliran 27

$C_{19}H_{38}N_2O_3$ yang digunakan adalah dengan konsentrasi 30%

$C_{19}H_{38}N_2O_3$ yang diperlukan adalah :

$C_{19}H_{38}N_2O_3$ = 2,5% × Total sabun

= 2,5% × 2.197,2207 $\frac{kg}{jam}$

= 54,9305 $\frac{kg}{jam}$

$C_{19}H_{38}N_2O_{3(l)}$ = 30% × 54,9305 $\frac{kg}{jam}$ = 19,2257 $\frac{kg}{jam}$

$H_2O_{(l)}$ = 70% × 54,9305 $\frac{kg}{jam}$ = 35,7048 $\frac{kg}{jam}$

➢ **Output**

- Aliran 28

1) $H_2O_{(l)}$ = (824,5022 + 0,0439 + 0,4394 + 1,0986 + 35,7048) $\frac{kg}{jam}$

= 861,7891 $\frac{kg}{jam}$

2) $C_6H_{10}O_{(l)}$ = 0,1257 $\frac{kg}{jam}$

3) $C_7H_{14}O_{(l)}$ = 0,0779 $\frac{kg}{jam}$

4) $C_8H_{16}O_{(l)}$ = 0,3531 $\frac{kg}{jam}$

5) $C_9H_{18}O_{(l)}$ = 0,0007 $\frac{kg}{jam}$

6) $C_{29}H_{50}O_{2(l)}$ = 6,5664 $\frac{kg}{jam}$

7) $C_{12}H_{24}O_{2(l)}$ = 0,0077 $\frac{kg}{jam}$

8) $C_{14}H_{28}O_{2(l)}$ = 0,0568 $\frac{kg}{jam}$

9) $C_{16}H_{32}O_{2(l)}$ = 2,4526 $\frac{kg}{jam}$

10) $C_{18}H_{34}O_{2(l)}$ = 1,9540 $\frac{kg}{jam}$

11) $C_{27}H_{46}O_{(l)}$ = 10,4920 $\frac{kg}{jam}$

12) $C_{18}H_{32}O_{2(l)}$ = 0,5419 $\frac{kg}{jam}$

13) $C_{18}H_{36}O_{2(l)}$ = 0,2383 $\frac{kg}{jam}$

14) $C_{30}H_{50(l)}$ = 5,2532 $\frac{kg}{jam}$

15) $C_{57}H_{104}O_{6(l)}$ = 1,4660 $\frac{kg}{jam}$

16) $KOH_{(l)}$ = 14,7476 $\frac{kg}{jam}$

17) $K_2CO_{3(l)}$ = 5,1710 $\frac{kg}{jam}$

18) $C_{12}H_{23}O_2K_{(l)}$ = 1,8117 $\frac{kg}{jam}$

19) $C_{14}H_{27}O_2K_{(l)}$ = 13,1525 $\frac{kg}{jam}$

20) $C_{16}H_{31}O_2K_{(l)}$ = 553,0023 $\frac{kg}{jam}$

21) $C_{18}H_{35}O_2K_{(l)}$ = 53,5878 $\frac{kg}{jam}$

22) $C_{18}H_{33}O_2K_{(l)}$ = 567,3742 $\frac{kg}{jam}$

23) $C_{18}H_{31}O_2K_{(l)}$ = 230,8503 $\frac{kg}{jam}$

24) $C_{10}H_{16}N_2O_{8(l)} = 4{,}3505 \frac{kg}{jam}$

25) $C_{13}H_9Cl_3N_2O_{(l)} = 21{,}5328 \frac{kg}{jam}$

26) $C_3H_8O_{3(l)} = (12{,}2268 + 218{,}6235) \frac{kg}{jam} = 230{,}8503 \frac{kg}{jam}$

27) $C_{16}H_{10}N_2Na_2O_7S_{2(l)} = 21{,}9722 \frac{kg}{jam}$

28) $C_{19}H_{38}N_2O_{3(l)} = 19{,}2257 \frac{kg}{jam}$

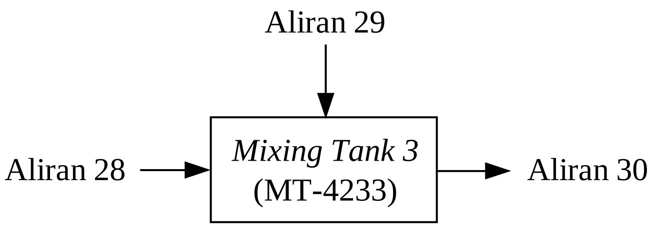
Tabel A.30 Neraca Massa *Mixing Tank 2*

Komponen	Masuk							Keluar	
	Aliran 21		Aliran 23	Aliran 24	Aliran 25	Aliran 26	Aliran 27	Aliran 28	
	Massa (kg/jam)	%	Massa (kg/jam)	Massa (kg/jam)	Massa (kg/jam)	Massa (kg/jam)	Massa (kg/jam)	Massa (kg/jam)	%
H_2O	824,5022	37,5248%	0,0439	0,4394		1,0986	35,7048	861,7891	34,1951%
$C_6H_{10}O$	0,1257	0,0057%						0,1257	0,0050%
$C_7H_{14}O$	0,0779	0,0035%						0,0779	0,0031%
$C_8H_{16}O$	0,3531	0,0161%						0,3531	0,0140%
$C_9H_{18}O$	0,0007	0,00003%						0,0007	0,00003%
$C_{29}H_{50}O_2$	6,5664	0,2989%						6,5664	0,2605%
$C_{12}H_{24}O_2$	0,0077	0,0003%						0,0077	0,0003%
$C_{14}H_{28}O_2$	0,0568	0,0026%						0,0568	0,0023%
$C_{16}H_{32}O_2$	2,4526	0,1116%						2,4526	0,0973%
$C_{18}H_{34}O_2$	1,9540	0,0889%						1,9540	0,0775%
$C_{27}H_{46}O$	10,4920	0,4775%						10,4920	0,4163%
$C_{18}H_{32}O_2$	0,5419	0,0247%						0,5419	0,0215%
$C_{18}H_{36}O_2$	0,2383	0,0108%						0,2383	0,0095%
$C_{30}H_{50}$	5,2532	0,2391%						5,2532	0,2084%
$C_{57}H_{104}O_6$	1,4660	0,0667%						1,4660	0,0582%
KOH	14,7476	0,6712%						14,7476	0,5852%
K_2CO_3	5,1710	0,2353%						5,1710	0,2052%
$C_{12}H_{23}O_2K$	1,8117	0,0825%						1,8117	0,0719%
$C_{14}H_{27}O_2K$	13,1525	0,5986%						13,1525	0,5219%
$C_{16}H_{31}O_2K$	553,0023	25,1683%						553,0023	21,9427%
$C_{18}H_{35}O_2K$	53,5875	2,4389%						53,5875	2,1263%

$C_{18}H_{33}O_2K$	567,3742	25,8224%						567,3742	22,5130%
$C_{18}H_{31}O_2K$	122,0585	5,5551%						122,0585	4,8432%
$C_3H_8O_3$	12,2268	0,5565%				218,6235		230,8503	9,1600%
$C_{10}H_{16}N_2O_8$			4,3505					4,3505	0,1726%
$C_{13}H_9Cl_3N_2O$				21,5328				21,5328	0,8544%
$C_{16}H_{10}N_2Na_2O_7S_2$					21,9722			21,9722	0,8718%
$C_{19}H_{38}N_2O_3$							19,2257	19,2257	0,7629%
Sub total	**2197,2207**	**100%**	**4,3944**	**21,9722**	**21,9722**	**219,7221**	**54,9305**	**2.520,2121**	**100%**
Total	**2.520,2121**							**2.520,2121**	

10. *Mixing Tank 3*

Fungsi : Mencampurkan produk keluaran *Mixing tank* dengan *Essential oil* (minyak kayu manis).



Kondisi Operasi:

- Temperatur : 30 °C
- Tekanan : 1 atm

Aliran 28 : Produk keluaran *Mixing Tank 2*
Aliran 29 : *Essential oil* (Minyak kayu manis)
Aliran 30 : Produk sabun cair

Berdasarkan (*The Ultimate Guide To Soap, 2019*), jumlah penggunaan *essential oil* sebagai pewangi dalam produk sabun adalah 0,1% - 0,2% **(0,2%)** dari jumlah total sabun.

Neraca massa total :

Aliran 28 + Aliran 29 = Aliran 30

$$2.520,2121 \frac{kg}{jam} = 35,0404 \frac{kg}{jam} = 2.525,2525 \frac{kg}{jam}$$

Neraca massa komponen :

- **Input**
  - Aliran 28

1) $H_2O_{(l)}$ $= 34,1951\% \times 2.520,2121 \frac{kg}{jam} = 861,7891 \frac{kg}{jam}$
2) $C_6H_{10}O_{(l)}$ $= 0,0050\% \times 2.520,2121 \frac{kg}{jam} = 0,1257 \frac{kg}{jam}$
3) $C_7H_{14}O_{(l)}$ $= 0,0031\% \times 2.520,2121 \frac{kg}{jam} = 0,0779 \frac{kg}{jam}$
4) $C_8H_{16}O_{(l)}$ $= 0,0140\% \times 2.520,2121 \frac{kg}{jam} = 0,3531 \frac{kg}{jam}$

5) $C_9H_{18}O_{(l)}$ $= 0{,}00003\% \times 2.520{,}2121 \frac{kg}{jam} = 0{,}0007 \frac{kg}{jam}$

6) $C_{29}H_{50}O_{2(l)}$ $= 0{,}2605\% \times 2.520{,}2121 \frac{kg}{jam} = 6{,}5664 \frac{kg}{jam}$

7) $C_{12}H_{24}O_{2(l)}$ $= 0{,}0003\% \times 2.520{,}2121 \frac{kg}{jam} = 0{,}0077 \frac{kg}{jam}$

8) $C_{14}H_{28}O_{2(l)}$ $= 0{,}0023\% \times 2.520{,}2121 \frac{kg}{jam} = 0{,}0568 \frac{kg}{jam}$

9) $C_{16}H_{32}O_{2(l)}$ $= 0{,}0973\% \times 2.520{,}2121 \frac{kg}{jam} = 2{,}4526 \frac{kg}{jam}$

10) $C_{18}H_{34}O_{2(l)}$ $= 0{,}0775\% \times 2.520{,}2121 \frac{kg}{jam} = 1{,}9540 \frac{kg}{jam}$

11) $C_{27}H_{46}O_{(l)}$ $= 0{,}4163\% \times 2.520{,}2121 \frac{kg}{jam} = 10{,}4920 \frac{kg}{jam}$

12) $C_{18}H_{32}O_{2(l)}$ $= 0{,}0215\% \times 2.520{,}2121 \frac{kg}{jam} = 0{,}5419 \frac{kg}{jam}$

13) $C_{18}H_{36}O_{2(l)}$ $= 0{,}0095\% \times 2.520{,}2121 \frac{kg}{jam} = 0{,}2383 \frac{kg}{jam}$

14) $C_{30}H_{50(l)}$ $= 0{,}2084\% \times 2.520{,}2121 \frac{kg}{jam} = 5{,}2532 \frac{kg}{jam}$

15) $C_{57}H_{104}O_{6(l)}$ $= 0{,}0582\% \times 2.520{,}2121 \frac{kg}{jam} = 1{,}4660 \frac{kg}{jam}$

16) $KOH_{(l)}$ $= 0{,}5852\% \times 2.520{,}2121 \frac{kg}{jam} = 14{,}7476 \frac{kg}{jam}$

17) $K_2CO_{3(l)}$ $= 0{,}2052\% \times 2.520{,}2121 \frac{kg}{jam} = 5{,}1710 \frac{kg}{jam}$

18) $C_{12}H_{23}O_2K_{(l)}$ $= 0{,}0719\% \times 2.520{,}2121 \frac{kg}{jam} = 1{,}8117 \frac{kg}{jam}$

19) $C_{14}H_{27}O_2K_{(l)}$ $= 0{,}5219\% \times 2.520{,}2121 \frac{kg}{jam} = 13{,}1525 \frac{kg}{jam}$

20) $C_{16}H_{31}O_2K_{(l)}$ $= 21{,}9427\% \times 2.520{,}2121 \frac{kg}{jam} = 553{,}0023 \frac{kg}{jam}$

21) $C_{18}H_{35}O_2K_{(l)}$ $= 2{,}1263\% \times 2.520{,}2121 \frac{kg}{jam} = 53{,}5875 \frac{kg}{jam}$

22) $C_{18}H_{33}O_2K_{(l)}$ $= 22{,}5130\% \times 2.520{,}2121 \frac{kg}{jam} = 567{,}3742 \frac{kg}{jam}$

23) $C_{18}H_{31}O_2K_{(l)}$ $= 4{,}8432\% \times 2.520{,}2121 \frac{kg}{jam} = 122{,}0585 \frac{kg}{jam}$

24) $C_{10}H_{16}N_2O_{8(l)}$ $= 0{,}1726\% \times 2.520{,}2121 \frac{kg}{jam} = 4{,}3505 \frac{kg}{jam}$

25) $C_{13}H_9Cl_3N_2O_{(l)}$ $= 0{,}8544\% \times 2.520{,}2121 \frac{kg}{jam} = 21{,}5328 \frac{kg}{jam}$

26) $C_3H_8O_{3(l)}$ $= 9{,}1600\% \times 2.520{,}2121 \frac{kg}{jam} = 230{,}8503 \frac{kg}{jam}$

27) $C_{16}H_{10}N_2Na_2O_7S_{2(l)}$ = 0,8718% × 2.520,2121 $\frac{kg}{jam}$ = 21,9722 $\frac{kg}{jam}$

28) $C_{19}H_{38}N_2O_{3(l)}$ = 0,7629% × 2.520,2121 $\frac{kg}{jam}$ = 19,2257 $\frac{kg}{jam}$

- Aliran 22

1) $C_9H_8O_{(l)}$ = 0,2% × 2.520,2121 $\frac{kg}{jam}$ = 5,0404 $\frac{kg}{jam}$

➢ **Output**

- Aliran 23

1) $H_2O_{(l)}$ = 861,7891 $\frac{kg}{jam}$
2) $C_6H_{10}O_{(l)}$ = 0,1257 $\frac{kg}{jam}$
3) $C_7H_{14}O_{(l)}$ = 0,0779 $\frac{kg}{jam}$
4) $C_8H_{16}O_{(l)}$ = 0,3531 $\frac{kg}{jam}$
5) $C_9H_{18}O_{(l)}$ = 0,0007 $\frac{kg}{jam}$
6) $C_{29}H_{50}O_{2(l)}$ = 6,5664 $\frac{kg}{jam}$
7) $C_{12}H_{24}O_{2(l)}$ = 0,0077 $\frac{kg}{jam}$
8) $C_{14}H_{28}O_{2(l)}$ = 0,0568 $\frac{kg}{jam}$
9) $C_{16}H_{32}O_{2(l)}$ = 2,4526 $\frac{kg}{jam}$
10) $C_{18}H_{34}O_{2(l)}$ = 1,9540 $\frac{kg}{jam}$
11) $C_{27}H_{46}O_{(l)}$ = 10,4920 $\frac{kg}{jam}$
12) $C_{18}H_{32}O_{2(l)}$ = 0,5419 $\frac{kg}{jam}$
13) $C_{18}H_{36}O_{2(l)}$ = 0,2383 $\frac{kg}{jam}$
14) $C_{30}H_{50(l)}$ = 5,2532 $\frac{kg}{jam}$
15) $C_{57}H_{104}O_{6(l)}$ = 1,4660 $\frac{kg}{jam}$
16) $KOH_{(l)}$ = 14,7476 $\frac{kg}{jam}$
17) $K_2CO_{3(l)}$ = 5,1710 $\frac{kg}{jam}$
18) $C_{12}H_{23}O_2K_{(l)}$ = 1,8117 $\frac{kg}{jam}$
19) $C_{14}H_{27}O_2K_{(l)}$ = 13,1525 $\frac{kg}{jam}$
20) $C_{16}H_{31}O_2K_{(l)}$ = 553,0023 $\frac{kg}{jam}$
21) $C_{18}H_{35}O_2K_{(l)}$ = 53,5875 $\frac{kg}{jam}$
22) $C_{18}H_{33}O_2K_{(l)}$ = 567,3742 $\frac{kg}{jam}$
23) $C_{18}H_{31}O_2K_{(l)}$ = 122.0585 $\frac{kg}{jam}$
24) $C_{10}H_{16}N_2O_{8(l)}$ = 4,3505 $\frac{kg}{jam}$
25) $C_{13}H_9Cl_3N_2O_{(l)}$ = 21,5328 $\frac{kg}{jam}$
26) $C_3H_8O_{3(l)}$ = 230,8503 $\frac{kg}{jam}$
27) $C_{16}H_{10}N_2Na_2O_7S_{2(l)}$ = 21,972 $\frac{kg}{jam}$
28) $C_{19}H_{38}N_2O_{3(l)}$ = 19,2257 $\frac{kg}{jam}$
29) $C_9H_8O_{(l)}$ = 5,0404 $\frac{kg}{jam}$

Tabel A.31 Neraca Massa *Mixing Tank 3*

Komponen	Masuk				Keluar	
	Aliran 21		Aliran 22		Aliran 23	
	Massa (kg/jam)	%	Massa (kg/jam)	%	Massa (kg/jam)	%
H_2O	861,7891	34,1951%			861,7891	34,1268%
$C_6H_{10}O$	0,1257	0,0050%			0,1257	0,0050%
$C_7H_{14}O$	0,0779	0,0031%			0,0779	0,0031%
$C_8H_{16}O$	0,3531	0,0140%			0,3531	0,0140%
$C_9H_{18}O$	0,0007	0,00003%			0,0007	0,00003%
$C_{29}H_{50}O_2$	6,5664	0,2605%			6,5664	0,2600%
$C_{12}H_{24}O_2$	0,0077	0,0003%			0,0077	0,0003%
$C_{14}H_{28}O_2$	0,0568	0,0023%			0,0568	0,0023%
$C_{16}H_{32}O_2$	2,4526	0,0973%			2,4526	0,0971%
$C_{18}H_{34}O_2$	1,9540	0,0775%			1,9540	0,0774%
$C_{27}H_{46}O$	10,4920	0,4163%			10,4920	0,4155%
$C_{18}H_{32}O_2$	0,5419	0,0215%			0,5419	0,0215%
$C_{18}H_{36}O_2$	0,2383	0,0095%			0,2383	0,0094%
$C_{30}H_{50}$	5,2532	0,2084%			5,2532	0,2080%
$C_{57}H_{104}O_6$	1,4660	0,0582%			1,4660	0,0581%
KOH	14,7476	0,5852%			14,7476	0,5840%
K_2CO_3	5,1710	0,2052%			5,1710	0,2048%
$C_{12}H_{23}O_2K$	1,8117	0,0719%			1,8117	0,0717%
$C_{14}H_{27}O_2K$	13,1525	0,5219%			13,1525	0,5208%
$C_{16}H_{31}O_2K$	553,0023	21,9427%			553,0023	21,8989%
$C_{18}H_{35}O_2K$	53,5875	2,1263%			53,5875	2,1221%
$C_{18}H_{33}O_2K$	567,3742	22,5130%			567,3742	22,4680%
$C_{18}H_{31}O_2K$	122,0585	4,8432%			122,0585	4,8335%
$C_3H_8O_3$	230,8503	9,1600%			230,8503	9,1417%
$C_{10}H_{16}N_2O_8$	4,3505	0,1726%			4,3505	0,1723%
$C_{13}H_9C_{13}N_2O$	21,5328	0,8544%			21,5328	0,8527%
$C_{16}H_{10}N_2Na_2O_7S_2$	21,9722	0,8718%			21,9722	0,8701%
$C_{19}H_{38}N_2O_3$	19,2257	0,7629%			19,2257	0,7613%
C_9H_8O			5,0404	100%	5,0404	0,1996%
Sub total	**2520,2121**	**100%**	**5,0404**	**100%**	**2.525,2525**	**100%**
Total	**2.525,2525**				**2.525,2525**	

LAMPIRAN B. NERACA ENERGI

- Persamaan yang digunakan untuk menghitung nilai panas (Q)
  Menggunakan data Cp dalam bentuk konstanta
  Untuk panas sensibel **$Q = m\ Cp\ \Delta T$**

  Untuk panas laten **$Q = m\ \lambda$**

Data Cp konstanta dapat diperoleh dari Carl L. Yaws *Chemical Properties Handbook* dan Perry's *Chemical Handbook* Vol.7 hal 354. Sedangkan data Cp konstanta untuk bahan yang dihitung berdasarkan gugus fungsi dapat dilihat pada buku Perry's *Chemical Handbook* Vol.7 hal 354.

- Persamaan yang digunakan untuk menghitung panas reaksi (Qr)

$$Q_R = -\Delta H_R$$

$$\Delta H_R = \Delta H^o_R + (\Delta H \text{ produk} - \Delta H \text{ reaktan})$$

$$\Delta H^o_R = \sum \Delta H^o_f \text{ produk} - \sum \Delta H^o_f \text{ reaktan}$$

$$\Delta H \text{ produk} = \sum (m \cdot C_p \cdot \Delta T) \text{ produk}$$

$$\Delta H \text{ reaktan} = \sum (m \cdot C_p \cdot \Delta T) \text{ reaktan}$$

Nilai kapasitas panas diperoleh dari Perry's *Chemical Engineers*' Ed. 7^{th} halaman 354.

Tabel B.1 Nilai Kapasitas Panas Komponen

Komponen	**Fasa**	**Cp (kkal/kg.K)**
$C_{12}H_{24}O_2$	Liquid	0,5023
$C_{14}H_{28}O_2$	Liquid	0,5043
$C_{16}H_{32}O_2$	Liquid	0,5058
$C_{18}H_{36}O_2$	Liquid	0,5071
$C_{18}H_{34}O_2$	Liquid	0,4953
$C_{18}H_{32}O_2$	Liquid	0,4470
$C_{57}H_{104}O_6$	Liquid	0,4020
$C_{29}H_{50}O_2$	Liquid	0,4004
$C_{27}H_{46}O$	Liquid	0,4102
$C_{30}H_{50}$	Liquid	0,4106
H_2O	Liquid	0,9902
H_2O	Gas	0,4170
$C_8H_{16}O$	Liquid	0,4134
$C_6H_{10}O$	Liquid	0,3763
$C_9H_{18}O$	Liquid	0,4164
$C_7H_{14}O$	Liquid	0,4097
$C_{12}H_{23}O_2K$	Liquid	0,4317
$C_{14}H_{27}O_2K$	Liquid	0,4408
$C_{16}H_{31}O_2K$	Liquid	0,4482
$C_{18}H_{35}O_2K$	Liquid	0,4543
$C_{18}H_{33}O_2K$	Liquid	0,4436
$C_{18}H_{31}O_2K$	Liquid	0,4008
KOH	Solid	0,2707
KOH	Liquid	0,3584
$C_{10}H_{16}N_2O_8$	Solid	0,3066
$C_{13}H_9C_{13}N_2O$	Solid	0,2533
$C_3H_8O_3$	Liquid	0,3464
$C_{16}H_{10}N_2Na_2O_7S_2$	Solid	0,2427
C_9H_8O	Liquid	0,3111
K_2CO_3	Liquid	0,1882
$C_{19}H_{38}N_2O_3$	Liquid	0,3995

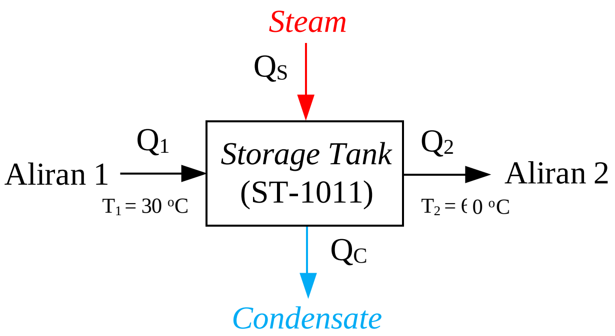
Nilai data ΔH_f dapat diperoleh dari Perry's *Chemical Engineers*' Ed. 7th halaman 349 dan Atkin's Pyhsical Chemistry Ed.11th halaman 874-877.

Tabel B.2 Nilai Panas Pembentukan Komponen

Komponen	**ΔH_f^o (kkal/kmol)**
$C_{12}H_{24}O_2$	-169,4780
$C_{14}H_{28}O_2$	-179,3375
$C_{16}H_{32}O_2$	-189,1971
$C_{18}H_{36}O_2$	-199,0566
$C_{18}H_{34}O_2$	-172,9890
$C_{18}H_{32}O_2$	-146,9213
$C_{57}H_{104}O_6$	-456,1290
$C_{12}H_{23}O_2K$	-148,2684
$C_{14}H_{27}O_2K$	-158,1280
$C_{16}H_{31}O_2K$	-167,9876
$C_{18}H_{35}O_2K$	-177,8471
$C_{18}H_{33}O_2K$	-151,7795
$C_{18}H_{31}O_2K$	-125,7118
KOH	-101,4522
H_2O	-68,2694
$C_3H_8O_3$	-159,9313

1. *Storage Tank PFAD*

Fungsi : Menyimpan dan mencairkan *Palm fatty acid distillate (PFAD).*



Kondisi operasi:

- Tekanan : 1 atm
- Temperatur : 60 °C

  T_{in} : 30 °C = 303,15 K

  T_{out} : 60 °C = 333,15 K

T_{steam} : 242 °C = 515,15 K

➢ **Input**

- **Q_1**

T_{in} : 30 °C = 303,15 K

T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	dT (K)	Q_1 (kkal/jam)
H_2O	1,0732	0,9902	5	5,3135
$C_6H_{10}O$	17,5472	0,3763	5	33,0132
$C_7H_{14}O$	4,5623	0,4097	5	9,3448
$C_8H_{16}O$	6,3170	0,4134	5	13,0570
$C_9H_{18}O$	0,0140	0,4164	5	0,0292
$C_{29}H_{50}O_2$	6,7077	0,4004	5	13,4276
$C_{12}H_{24}O_2$	2,1921	0,5023	5	5,5054
$C_{14}H_{28}O_2$	13,1524	0,5043	5	33,1625
$C_{16}H_{32}O_2$	519,8479	0,5058	5	1.314,7599
$C_{18}H_{34}O_2$	401,1476	0,4953	5	993,5307
$C_{27}H_{46}O$	10,7323	0,4102	5	22,0109
$C_{18}H_{32}O_2$	110,3704	0,4470	5	246,7015
$C_{18}H_{36}O_2$	49,3214	0,5071	5	125,0456
$C_{30}H_{50}$	5,3661	0,4106	5	11,0167
$C_{57}H_{104}O_6$	193,1806	0,4020	5	388,2721
Total	**1.341,5322**			**3.214,1907**

➢ **Output**

Q_2

T_{out} : 60 °C = 333,15 K

T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	dT (K)	Q_2 (kkal/jam)
H_2O	1,0732	0,9902	35	37,1948
$C_6H_{10}O$	17,5472	0,3763	35	231,0921
$C_7H_{14}O$	4,5623	0,4097	35	65,4138
$C_8H_{16}O$	6,3170	0,4134	35	91,3992
$C_9H_{18}O$	0,0140	0,4164	35	0,2046
$C_{29}H_{50}O_2$	6,7077	0,4004	35	93,9931
$C_{12}H_{24}O_2$	2,1921	0,5023	35	38,5380
$C_{14}H_{28}O_2$	13,1524	0,5043	35	232,1375

$C_{16}H_{32}O_2$	519,8479	0,5058	35	9.203,3192
$C_{18}H_{34}O_2$	401,1476	0,4953	35	6.954,7149
$C_{27}H_{46}O$	10,7323	0,4102	35	154,0762
$C_{18}H_{32}O_2$	110,3704	0,4470	35	1.726,9105
$C_{18}H_{36}O_2$	49,3214	0,5071	35	875,3195
$C_{30}H_{50}$	5,3661	0,4106	35	77,1170
$C_{57}H_{104}O_6$	193,1806	0,4020	35	2.717,9046
Total	**1.341,5322**			**22.499,3349**

- **Kebutuhan *Steam***

$Q_{steam} = Q_{keluar} - Q_{masuk}$

Q_{steam} = 22.499,3349 – 3.214,1907 = 19.285,1442 kkal/jam

Media pemanas yang digunakan adalah *saturated steam* pada temperatur 242 ^oC, sehingga diperoleh data dari tabel F.1 *Saturated Steam* Halaman 669 Smith van ness sebagai berikut:

H_{liq} = 1047,2 kJ/kg = 250,1672 kkal/kg

H_{vap} = 2.802 kJ/kg = 669,3741 kkal/kg

λ_s = 1.754,8 kJ/kg = 419,2069 kkal/kg

$\Delta Q = m_s \times \lambda_s$

$$m_s = \frac{\Delta Q}{\lambda_s} = \frac{19.285,1442 \text{ kkal/jam}}{419,2069 \text{ kkal/kg}} = 46,0039 \text{ kg/jam}$$

Panas *steam* masuk

$Q_s = m_s \times H_{vap}$

Q_s = 46,0039 kg/jam x 669,3741 kkal/kg = 30.793,8079 kkal/jam

Panas *condensate* keluar

$Q_c = m_s \times H_{liquid}$

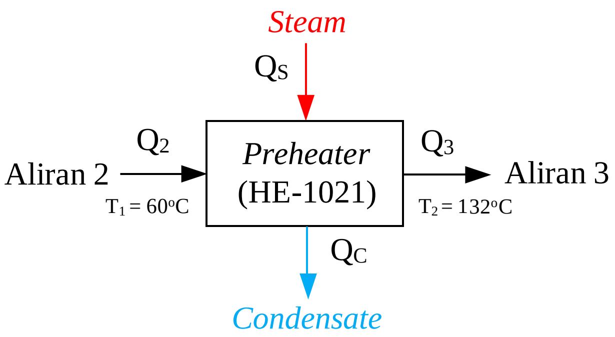
Q_c = 46,0039 kg/jam x 250,1672 kkal/kg = 11.508,6637 kkal/jam

Tabel B.3 Neraca Energi *Storage Tank PFAD*

Komponen	Masuk (kkal/jam)	Keluar (kkal/jam)
Q_1	3.214,1907	
Q_2		22.499,3349
Qs	30.793,8079	
Q_C		11.508,6637
Total	**34.007,9986**	**34.007,9986**

2. *Preheater*

Fungsi : Memanaskan umpan sebelum *Deodorizer*, dengan tujuan untuk mengurangi beban panas pada *Deodorizer*.



Kondisi operasi:

- Tekanan : 1 atm
- Temperatur : 132 °C

T_{in} : 60 °C = 333,15 K

T_{out} : 132 °C = 405,15 K

T_{steam} : 242 °C = 515,15 K

Keterangan:

Q_2 : Panas komponen masuk

Q_3 : Panas komponen keluar

Q_S : Panas *steam* masuk

Q_C : Panas *condensate* keluar

➢ **Input**

Q_2

T_{in} : 60 °C = 333,15 K

T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	dT (K)	Q_2 (kkal/jam)
H_2O	1,0732	0,9902	35	37,1948
$C_6H_{10}O$	17,5472	0,3763	35	231,0921
$C_7H_{14}O$	4,5623	0,4097	35	65,4138
$C_8H_{16}O$	6,3170	0,4134	35	91,3992
$C_9H_{18}O$	0,0140	0,4164	35	0,2046
$C_{29}H_{50}O_2$	6,7077	0,4004	35	93,9931
$C_{12}H_{24}O_2$	2,1921	0,5023	35	38,5380

$C_{14}H_{28}O_2$	13,1524	0,5043	35	232,1375
$C_{16}H_{32}O_2$	519,8479	0,5058	35	9.203,3192
$C_{18}H_{34}O_2$	401,1476	0,4953	35	6.954,7149
$C_{27}H_{46}O$	10,7323	0,4102	35	154,0762
$C_{18}H_{32}O_2$	110,3704	0,4470	35	1.726,9105
$C_{18}H_{36}O_2$	49,3214	0,5071	35	875,3195
$C_{30}H_{50}$	5,3661	0,4106	35	77,1170
$C_{57}H_{104}O_6$	193,1806	0,4020	35	2.717,9046
Total	**1.341,5322**			**22.499,3349**

➢ **Output**

- **Q_3**

T_{out} : 132 °C = 405,15 K

T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	dT (K)	Q_3 (kkal/jam)
H_2O	1,0732	0,9902	107	47,8908
$C_6H_{10}O$	17,5472	0,3763	107	706,4815
$C_7H_{14}O$	4,5623	0,4097	107	199,9793
$C_8H_{16}O$	6,3170	0,4134	107	279,4206
$C_9H_{18}O$	0,0140	0,4164	107	0,6254
$C_{29}H_{50}O_2$	6,7077	0,4004	107	287,3503
$C_{12}H_{24}O_2$	2,1921	0,5023	107	117,8161
$C_{14}H_{28}O_2$	13,1524	0,5043	107	709,6774
$C_{16}H_{32}O_2$	519,8479	0,5058	107	28.135,8616
$C_{18}H_{34}O_2$	401,1476	0,4953	107	21.261,5570
$C_{27}H_{46}O$	10,7323	0,4102	107	471,0328
$C_{18}H_{32}O_2$	110,3704	0,4470	107	5.279,4122
$C_{18}H_{36}O_2$	49,3214	0,5071	107	2.675,9767
$C_{30}H_{50}$	5,3661	0,4106	107	235,7578
$C_{57}H_{104}O_6$	193,1806	0,4020	107	8.309,0225
Total	**1.341,5322**			**68.717,8619**

- **Panas Penguapan (Q_v)**

T_v : 132 °C = 405,15 K

T_{ref} : 25 °C = 298,15 K

Komponen	BM	m (kg/jam)	A	Tc (K)	n	ΔH (kkal/kg)	Q_v (kkal/jam)
H_2O	18	1,0732	52,053	647,13	0,321	0,5038	0,5407

$C_6H_{10}O$	98	17,5472	53,720	629,15	0,285	0,0004	0,0072
$C_7H_{14}O$	114	4,5623	62,190	611,55	0,403	1,9995	9,1224
$C_8H_{16}O$	128	6,3170	66,984	621,00	0,368	1,1190	7,0685
Total		**29,4997**					**16,7387**

- **Kebutuhan *Steam***

$Q_{steam} = Q_{keluar} - Q_{masuk}$

Q_{steam} = (68.717,8619 + 16,7387) – 22.499,3349 = 46.235,2658 kkal/jam

Media pemanas yang digunakan adalah *saturated steam* pada temperatur 242 °C, sehingga diperoleh data dari tabel F.1 *Saturated Steam* Halaman 669 Smith van ness sebagai berikut:

H_{liq} = 1047,2 kJ/kg = 250,1672 kkal/kg

H_{vap} = 2.802 kJ/kg = 669,3741 kkal/kg

λ_s = 1.754,8 kJ/kg = 419,2069 kkal/kg

$\Delta Q = m_s \times \lambda_s$

$$m_s = \frac{\Delta Q}{\lambda_s} = \frac{46.235,2658 \text{ kkal/jam}}{419,2069 \text{ kkal/kg}} = 110,2922 \text{ kg/jam}$$

Panas *steam* masuk

$Q_s = m_s \times H_{vap}$

Q_s = 110,2922 kg/jam x 669,3741 kkal/kg = 78.826,7693 kkal/jam

Panas *condensate* keluar

$Q_c = m_s \times H_{liquid}$

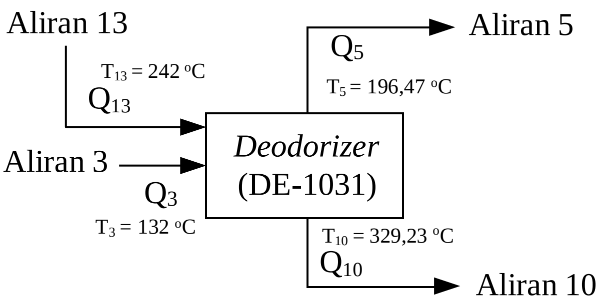
Q_c = 110,2922 kg/jam x 250,1672 kkal/kg = 27.591,5035 kkal/jam

Tabel B.4 Neraca Energi *Preheater*

Komponen	Masuk (kkal/jam)	Keluar (kkal/jam)
Q_2	22.499,3349	
Q_3		68.717,8619
Q_V		16,7387
Qs	73.826,7693	
Q_C		27.591,5035
Total	**96.326,1042**	**96.326,1042**

3. *Deodorizer*

Fungsi : Memisahkan *Palm fatty acid distillate (PFAD)* dari komponen-komponen yang menyebabkan bau.



Kondisi operasi:

- Tekanan : 0,008 atm
- Temperatur

T_{in} : 132 °C = 405,15 K

$T_{destilat}$: 196,47 °C = 469,62 K

T_{bottom} : 329,23 °C = 602,38 K

- **Input**
- **Q_3**

T_{in} : 132 °C = 405,15 K

T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	dT (K)	Q_3 (kkal/jam)
H_2O	1,0732	0,9902	107	47,8908
$C_6H_{10}O$	17,5472	0,3763	107	706,4815
$C_7H_{14}O$	4,5623	0,4097	107	199,9793
$C_8H_{16}O$	6,3170	0,4134	107	279,4206
$C_9H_{18}O$	0,0140	0,4164	107	0,6254
$C_{29}H_{50}O_2$	6,7077	0,4004	107	287,3503
$C_{12}H_{24}O_2$	2,1921	0,5023	107	117,8161
$C_{14}H_{28}O_2$	13,1524	0,5043	107	709,6774
$C_{16}H_{32}O_2$	519,8479	0,5058	107	28.135,8616
$C_{18}H_{34}O_2$	401,1476	0,4953	107	21.261,5570
$C_{27}H_{46}O$	10,7323	0,4102	107	471,0328
$C_{18}H_{32}O_2$	110,3704	0,4470	107	5.279,4122
$C_{18}H_{36}O_2$	49,3214	0,5071	107	2.675,9767

$C_{30}H_{50}$	5,3661	0,4106	107	235,7578
$C_{57}H_{104}O_6$	193,1806	0,4020	107	8.309,0225
Total	**1.341,5322**			**68.717,8619**

- **Q_{13}**

  T_{in} : 242 °C = 515,15 K

  T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	cP (kkal/kg.K)	dT (K)	Q_{13} (kkal/jam)
Steam	40,2460	0,4170	217	3.642,1601
Total	**40,2460**			**3.642,1601**

- **Panas Penguapan Reboiler, Q_{V1}**

  T_{in} : 226 °C = 499,34 K

  T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	A	Tc (K)	n	ΔHv (kkal/kg)	Q_{V1} (kkal/jam)
H_2O	1,97552	52,0530	647,130	0,321	0,4300	0,8495
$C_6H_{10}O$	32,14510	53,7200	629,150	0,285	0,0835	2,6846
$C_7H_{14}O$	8,27251	62,1900	611,550	0,403	0,0658	0,5444
$C_8H_{16}O$	10,99259	66,9840	621,000	0,368	0,0686	0,7543
$C_9H_{18}O$	0,02461	72,5480	640,000	0,376	0,0690	0,0017
$C_{29}H_{50}O_2$	0,01336				0,0558	0,0007
$C_{12}H_{24}O_2$	1,16394	130,5300	734,000	0,491	0,0891	0,1037
$C_{14}H_{28}O_2$	2,93563	127,6000	756,000	0,439	0,0832	0,2443
$C_{16}H_{32}O_2$	47,96672	92,1150	776,000	0,208	0,0694	3,3271
$C_{18}H_{34}O_2$	6,78990	134,6630	781,000	0,394	0,0763	0,5183
$C_{27}H_{46}O$	0,04817				0,0532	0,0026
$C_{18}H_{32}O_2$	0,27916	133,9370	775,000	0,399	0,0757	0,0211
$C_{18}H_{36}O_2$	1,56892	131,7120	799,000	0,417	0,0736	0,1155
$C_{30}H_{50}$	0,01062				0,0383	0,0004
$C_{57}H_{104}O_6$	0,00003				0,0322	9,E-07
Steam	74,27046	52,0530	647,130	0,321	0,4300	31,9388
Total	**188,45724**					**41,1068**

- **Panas Yang Diberikan Reboiler, Q_{rb}**

  T_{in} : 226 °C = 499,34 K

  T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	dT (K)	Q_{rb} (kkal/jam)
H_2O	1,9782	0,4170	201,19	165,9824
$C_6H_{10}O$	32,2734	0,3763	201,19	2.443,2018
$C_7H_{14}O$	8,3520	0,4097	201,19	688,3644
$C_8H_{16}O$	11,3529	0,4134	201,19	944,2255
$C_9H_{18}O$	0,0253	0,4164	201,19	2,1205
$C_{29}H_{50}O_2$	6,7138	0,4004	201,19	540,7911
$C_{12}H_{24}O_2$	2,7253	0,5023	201,19	275,4134
$C_{14}H_{28}O_2$	14,4972	0,5043	201,19	1.470,8338
$C_{16}H_{32}O_2$	541,8222	0,5058	201,19	55.139,4546
$C_{18}H_{34}O_2$	404,2582	0,4953	201,19	40.287,5991
$C_{27}H_{46}O$	10,7543	0,4102	201,19	887,4931
$C_{18}H_{32}O_2$	110,4983	0,4470	201,19	9.938,2571
$C_{18}H_{36}O_2$	50,0402	0,5071	201,19	5.104,8999
$C_{30}H_{50}$	5,3710	0,4106	201,19	443,6918
$C_{57}H_{104}O_6$	193,1806	0,4020	201,19	15.623,2609
Steam	74,2705	0,4170	201,19	6.231,5854
Total	**1.468,1135**			**140.187,1749**

- **Output**
  - **Produk Bawah (Bottom), Q_{10}**

T_{out} : 329,23 °C = 602,38 K

T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	dT (K)	Q_{10} (kkal/jam)
H_2O	0,0027	0,4170	304,23	0,3455
$C_6H_{10}O$	0,1283	0,3763	304,23	14,6845
$C_7H_{14}O$	0,0795	0,4097	304,23	9,9118
$C_8H_{16}O$	0,3603	0,4134	304,23	45,3108
$C_9H_{18}O$	0,0007	0,4164	304,23	0,0889
$C_{29}H_{50}O_2$	6,7004	0,4004	304,23	816,1242
$C_{12}H_{24}O_2$	1,5613	0,5023	304,23	238,5961
$C_{14}H_{28}O_2$	11,5616	0,5043	304,23	1.773,7350
$C_{16}H_{32}O_2$	493,8555	0,5058	304,23	75.997,2044
$C_{18}H_{34}O_2$	397,4683	0,4953	304,23	59.897,2818
$C_{27}H_{46}O$	10,7062	0,4102	304,23	1.336,0028
$C_{18}H_{32}O_2$	110,2191	0,4470	304,23	14.990,0719
$C_{18}H_{36}O_2$	48,4713	0,5071	304,23	7.477,2992
$C_{30}H_{50}$	5,3604	0,4106	304,23	669,5975
$C_{57}H_{104}O_6$	193,1806	0,4020	304,23	23.624,5582

Total	**1.279,6562**			**186.890,8127**

- **Produk Atas (Destilat), Q_5**

  T_{out} : 196,47°C = 469,62 K

  T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	dT (K)	Q_5 (kkal/jam)
H_2O	1,0705	0,4170	171,47	76,5502
$C_6H_{10}O$	17,4189	0,3763	171,47	1.123,8602
$C_7H_{14}O$	4,4827	0,4097	171,47	314,8804
$C_8H_{16}O$	5,9567	0,4134	171,47	422,2335
$C_9H_{18}O$	0,0133	0,4164	171,47	0,9522
$C_{29}H_{50}O_2$	0,0072	0,4004	171,47	0,4972
$C_{12}H_{24}O_2$	0,6307	0,5023	171,47	54,3235
$C_{14}H_{28}O_2$	1,5908	0,5043	171,47	137,5504
$C_{16}H_{32}O_2$	25,9924	0,5058	171,47	2.254,3860
$C_{18}H_{34}O_2$	3,6793	0,4953	171,47	312,5062
$C_{27}H_{46}O$	0,0261	0,4102	171,47	1,8359
$C_{18}H_{32}O_2$	0,1513	0,4470	171,47	11,5955
$C_{18}H_{36}O_2$	0,8502	0,5071	171,47	73,9182
$C_{30}H_{50}$	0,0058	0,4106	171,47	0,4052
$C_{57}H_{104}O_6$	0,00001	0,4020	171,47	0,0010
Steam	40,2460	0,4170	171,47	2.877,9360
Total	**102,1219**			**7.663,4315**

- **Panas Penguapan Destilat, Q_{V2}**

  T_{out} : 196,47°C = 469,62 K

  T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	A	Tc (K)	n	ΔH_v (kkal/kg)	Q_{V2} (kkal/jam)
H_2O	1,0705	52,0530	647,1300	0,3210	0,4561	0,4882
$C_6H_{10}O$	17,4189	53,7200	629,1500	0,2850	0,0886	1,5428
$C_7H_{14}O$	4,4827	62,1900	611,5500	0,4030	0,0723	0,3243
$C_8H_{16}O$	5,9567	66,9840	621,0000	0,3680	0,0744	0,4430
$C_9H_{18}O$	0,0133	72,5480	640,0000	0,3760	0,0742	0,0010
$C_{29}H_{50}O_2$	0,0072				0,0558	0,0004
$C_{12}H_{24}O_2$	0,6307	130,5300	734,0000	0,4910	0,0944	0,0596
$C_{14}H_{28}O_2$	1,5908	127,6000	756,0000	0,4390	0,0873	0,1389
$C_{16}H_{32}O_2$	25,9924	92,1150	776,0000	0,2080	0,0709	1,8416
$C_{18}H_{34}O_2$	3,6793	134,6630	781,0000	0,3940	0,0794	0,2922

$C_{27}H_{46}O$	0,0261				0,0532	0,0014
$C_{18}H_{32}O_2$	0,1513	133,9370	775,0000	0,3990	0,0788	0,0119
$C_{18}H_{36}O_2$	0,8502	131,7120	799,0000	0,4170	0,0766	0,0651
$C_{30}H_{50}$	0,0058				0,0383	0,0002
$C_{57}H_{104}O_6$	0,00001				0,0322	0,0000
Steam	40,2460	52,0530	647,1300	0,3210	0,4561	18,3557
Total	**102,1219**					**23,5661**

- **Beban Panas**

Beban panas yang diserap kondensor (Q_C)

$Q_3 + Q_{13} + Q_{rb} + Q_{V1} = Q_5 + Q_{10} + Q_C + Q_{V2}$

68.717,8619 + 3.642,1601 + 140.187,1749 + 41,1068 = 7.663,4315 + 186.890,8127 + Q_C + 23,5661

212.588,3037 = 194.577,8103 + Q_C

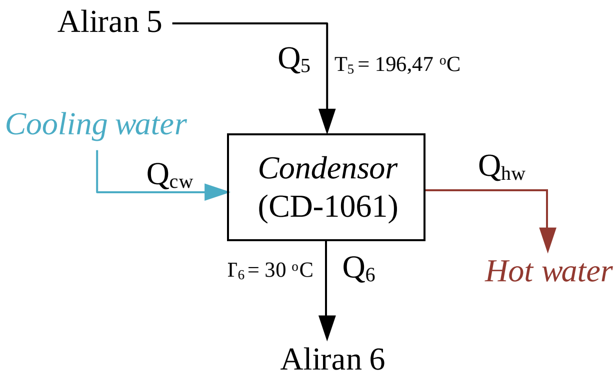
Q_C = 18.010,4934 kkal/jam

Tabel B.5 Neraca Energi *Deodorizer*

Komponen	Masuk (kkal/jam)	Keluar (kkal/jam)
Q_3	68.717,8619	
Q_{13}	3.642,1601	
Q_{rb}	140.187,1749	
Q_{V1}	41,1068	
Q_5		7.663,4315
Q_{10}		186.890,8127
Q_{V2}		23,5661
Q_C		18.010,4934
Total	**212.588,3037**	**212.588,3037**

4. *Condensor*

Fungsi : Menurunkan temperatur produk yang keluar dari bagian atas *Deodorizer* dan mengubah fasa destilat berupa uap menjadi cair.



Kondisi operasi:

- Tekanan : 1 atm
- Temperatur : 30 °C

T_{in} : 196,47 °C = 469,62 K

T_{out} : 30 °C = 303,15 K

$T_{cooling\ water}$: 28 °C = 301,15 K

Keterangan:

Q_5 : Panas uap yang masuk

Q_6 : Panas liquid keluar

Q_{cw} : Panas air pendingin masuk

Q_{hw} : Panas air pendingin keluar

Q_C : Panas yang diserap kondensor, $Q_C = Q_6 - Q_5$

Neraca energi total

$$Q\ masuk = Q\ keluar$$

$$Q_5 + Q_{cw} = Q_6 + Q_{hw}$$

Diketahui beban panas kondensor adalah Q_C = 18.010,49339 kkal/jam

$T_{cw\ in}$ = 28°C

$T_{hw\ out}$ = 38°C

T_{ref} = 25°C

Jumlah air pendingin yang dibutuhkan

$$m = \frac{Q_C}{Cp \times \Delta T} = \frac{18.010,49339\ kkal/jam}{1\ kkal/kg.C \times (38 - 28)\ C} = 1.801,0493\ kg/jam$$

Panas sensibel air pendingin masuk ($Q_{cw\ in}$):

$Q_{cw\ in}$ = m x Cp x ΔT

$Q_{cw\ in}$ = 1.801,0493 kg/jam x 1 kkal/kg.C x (28 – 25) C

$Q_{cw\ in}$ = 5.403,1480 kkal/jam

Panas sensibel air panas keluar ($Q_{hw\ out}$):

$Q_{hw\ out}$ = m x Cp x ΔT

$Q_{hw\ out}$ = 1.801,0493 kg/jam x 1 kkal/kg.C x (38 – 25) C

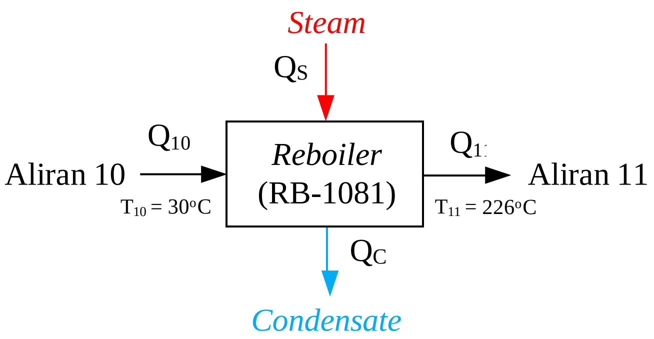
$Q_{hw\ out}$ = 23.413,6414 kkal/jam

Tabel B.6 Neraca Energi *Condensor*

Komponen	Masuk (kkal/jam)	Keluar (kkal/jam)
Q_{cw}	5.403,1480	
Q_{hw}		23.413,6414
Q_C	18.010,4934	
Total	**23.413,6414**	**23.413,6414**

5. *Reboiler*

Fungsi : Menguapkan sebagian campuran produk bawah hingga ke titik didihnya sebelum masuk ke *Deodorizer*.



Kondisi operasi:

- Tekanan : 1 atm
- Temperatur : 226 °C

T_{in}	: 30°C	= 303,15 K
T_{out}	: 226 °C	= 499,34 K
T_{steam}	: 242 °C	= 515,15 K

Keterangan:

Q_{10} : Panas liquid masuk

Q_{11} : Panas uap keluar

Q_S : Panas *steam* masuk

Q_C : Panas *condensate* keluar

Neraca energi total

Q masuk = Q keluar

$Q_{10} + Q_s = Q_{11} + Q_C$

Diketahui beban panas reboiler adalah Q_{rb} = 140.228,2817 kkal/jam. Media pemanas yang digunakan adalah *saturated steam* pada temperatur 242 ^oC, sehingga diperoleh data dari tabel F.1 *Saturated Steam* Halaman 669 Smith van ness sebagai berikut:

H_{liq} = 1047,2 kJ/kg = 250,1672 kkal/kg

H_{vap} = 2.802 kJ/kg = 669,3741 kkal/kg

λ_s = 1.754,8 kJ/kg = 419,2069 kkal/kg

$\Delta Q = m_s \times \lambda_s$

$$m_s = \frac{\Delta Q}{\lambda_s} = \frac{140.228,2817 \text{ kkal/jam}}{419,2069 \text{ kkal/kg}} = 334.\ 5085 \text{ kg/jam}$$

Panas *steam* masuk

$Q_s = m_s \times H_{vap}$

Q_s = 334. 5085 kg/jam x 669,3741 kkal/kg = 223.911,3548 kkal/jam

Panas *condensate* keluar

$Q_c = m_s \times H_{liquid}$

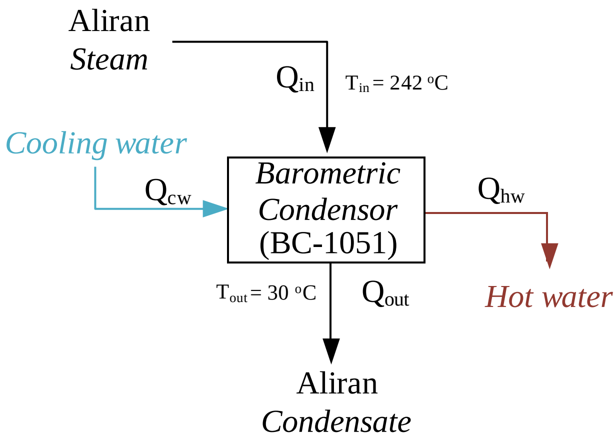
Q_c = 334. 5085 kg/jam x 250,1672 kkal/kg = 83.683,0731 kkal/jam

Tabel B.7 Neraca Energi *Reboiler*

Komponen	Masuk (kkal/jam)	Keluar (kkal/jam)
Q_S	223.911,3548	
Q_C		83.683,0731
Q_{rb}		140.228,2817
Total	**223.911,3548**	**223.911,3548**

6. *Barometric Condensor*

Fungsi : Mengkondensasi sebagian uap yang keluar dari steam jet ejector dan menjaga tekanan pada *deodorizer*.



Kondisi operasi:

- Tekanan : 1 atm
- Temperatur : 30 °C

T_{in}	: 242 °C	= 515,15 K
T_{out}	: 30 °C	= 303,15 K
$T_{cooling\ water}$	: 28 °C	= 301,15 K

Keterangan:

Q_{cw} : Panas air pendingin masuk

Q_{hw} : Panas air pendingin keluar

Diketahui beban panas *barometric condensor* adalah Q_C = 150.788,7605 kkal/jam

$T_{cw\ in}$ = 28°C

$T_{hw\ out}$ = 38°C

T_{ref} = 25°C

Jumlah air pendingin yang dibutuhkan

$$m = \frac{Q_C}{Cp \times \Delta T} = \frac{150.788,7605 \text{ kkal/jam}}{1 \text{ kkal/kg.C} \times (38 - 28) \text{ C}} = 15.078,8760 \text{ kg/jam}$$

Panas sensibel air pendingin masuk ($Q_{cw\ in}$):

$Q_{cw\ in}$ = m x Cp x ΔT

$Q_{cw\ in}$ = 15.078,8760 kg/jam x 1 kkal/kg.C x (28 – 25) C

$Q_{cw\ in}$ = 120.631,0084 kkal/jam

Panas sensibel air panas keluar ($Q_{hw\ out}$):

$Q_{hw\ out}$ = m x Cp x ΔT

$Q_{hw\ out}$ = 15.078,8760 kg/jam x 1 kkal/kg.C x (38 – 25) C

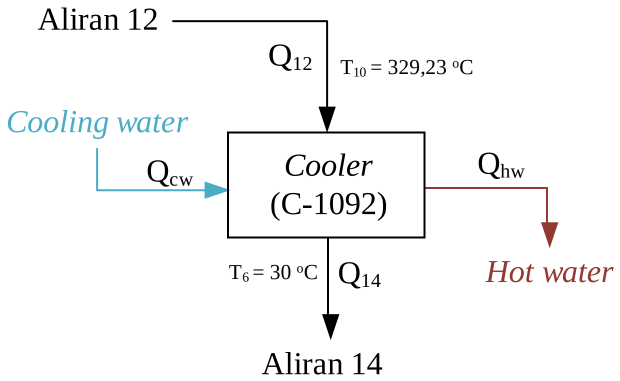
$Q_{hw\ out}$ = 271.419,7689 kkal/jam

Tabel B.8 Neraca Energi *Barometric Condensor*

Komponen	Masuk (kkal/jam)	Keluar (kkal/jam)
Q_{cw}	120.631,0084	
Q_{hw}		271.419,7689
Q_C	150.788,7605	
Total	**271.419,7689**	**271.419,7689**

7. *Cooler* 1

Fungsi : Menurunkan temperatur *bottom product deodorizer* sebelum masuk kedalam reaktor.



Kondisi operasi:

- Tekanan : 1 atm
- Temperatur : 30 °C

T_{in} : 329,23 °C = 602,38 K

T_{out} : 30 °C = 303,15 K

$T_{cooling\ water}$: 28 °C = 301,15 K

Keterangan:

Q_{12} : Panas liquid masuk

Q_{14} : Panas liquid keluar

Q_{cw} : Panas air pendingin masuk

Q_{hw} : Panas air pendingin keluar

Q_C : Panas yang diserap *cooler*, $Q_C = Q_{14} - Q_{12}$

- **Input**

Q_{12}

T_{in} : 329,23 °C = 602,38 K

T_{ref} : 25 °C = 298,15 K

Komponen	**m (kg/jam)**	**Cp (kkal/kg.K)**	**dT (K)**	**Q_{12} (kkal/jam)**
H_2O	0,0027	0,4170	304,23	0,3455
$C_6H_{10}O$	0,1283	0,3763	304,23	14,6845
$C_7H_{14}O$	0,0795	0,4097	304,23	9,9118
$C_8H_{16}O$	0,3603	0,4134	304,23	45,3108
$C_9H_{18}O$	0,0007	0,4164	304,23	0,0889
$C_{29}H_{50}O_2$	6,7004	0,4004	304,23	816,1242
$C_{12}H_{24}O_2$	1,5613	0,5023	304,23	238,5961
$C_{14}H_{28}O_2$	11,5616	0,5043	304,23	1.773,7350
$C_{16}H_{32}O_2$	493,8555	0,5058	304,23	75.997,2044
$C_{18}H_{34}O_2$	397,4683	0,4953	304,23	59.897,2818
$C_{27}H_{46}O$	10,7062	0,4102	304,23	1.336,0028
$C_{18}H_{32}O_2$	110,2191	0,4470	304,23	14.990,0719
$C_{18}H_{36}O_2$	48,4713	0,5071	304,23	7.477,2992
$C_{30}H_{50}$	5,3604	0,4106	304,23	669,5975
$C_{57}H_{104}O_6$	193,1806	0,4020	304,23	23.624,5582
Total	**1.279,6562**			**186.890,8127**

- **Output**

  - **Q_{14}**

T_{out} : 80 °C = 353,15 K

T_{ref} : 25 °C = 298,15 K

Komponen	**m (kg/jam)**	**Cp (kkal/kg.K)**	**dT (K)**	**Q_{14} (kkal/jam)**
H_2O	0,0027	0,9902	55	0,1483
$C_6H_{10}O$	0,1283	0,3763	55	2,6548

$C_7H_{14}O$	0,0795	0,4097	55	1,7919
$C_8H_{16}O$	0,3603	0,4134	55	8,1916
$C_9H_{18}O$	0,0007	0,4164	55	0,0161
$C_{29}H_{50}O_2$	6,7004	0,4004	55	147,5439
$C_{12}H_{24}O_2$	1,5613	0,5023	55	43,1349
$C_{14}H_{28}O_2$	11,5616	0,5043	55	320,6667
$C_{16}H_{32}O_2$	493,8555	0,5058	55	13.739,2408
$C_{18}H_{34}O_2$	397,4683	0,4953	55	10.828,5981
$C_{27}H_{46}O$	10,7062	0,4102	55	241,5308
$C_{18}H_{32}O_2$	110,2191	0,4470	55	2.709,9972
$C_{18}H_{36}O_2$	48,4713	0,5071	55	1.351,7920
$C_{30}H_{50}$	5,3604	0,4106	55	121,0540
$C_{57}H_{104}O_6$	193,1806	0,4020	55	4.270,9926
Total	**1.279,6562**			**33.787,3535**

- **Beban Panas**

  $\Delta Q = Q_{12} - Q_{14}$

  ΔQ = 186.890,8127 kkal/jam - 33.787,3535 kkal/jam

  ΔQ = 153.103,4592 kkal/jam

- **Kebutuhan Pendingin**

  Jumlah air pendingin yang dibutuhkan

  $$m = \frac{Q}{Cp \times \Delta T} = \frac{153.103,4592 \text{ kkal/jam}}{1 \text{ kkal/kg.C} \times (38 - 28) \text{ C}} = 15.310,3459 \text{ kg/jam}$$

  Panas sensibel air pendingin masuk ($Q_{cw\ in}$):

  $Q_{cw\ in} = m \times Cp \times \Delta T$

  $Q_{cw\ in}$ = 15.310,3459 kg/jam x 1 kkal/kg.C x (28 – 25) C

  $Q_{cw\ in}$ = 45.931,0378 kkal/jam

  Panas sensibel air panas keluar ($Q_{hw\ out}$):

  $Q_{hw\ out} = m \times Cp \times \Delta T$

  $Q_{hw\ out}$ = 15.310,3459 kg/jam x 1 kkal/kg.C x (38 – 25) C

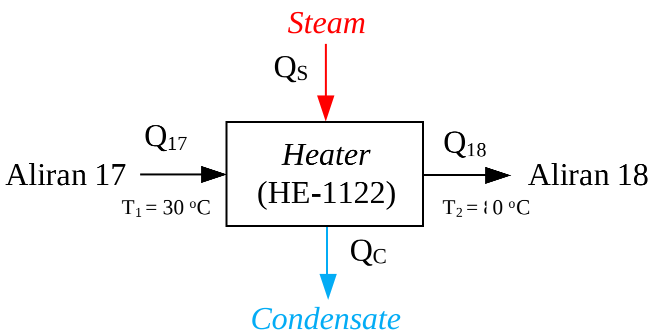
  $Q_{hw\ out}$ = 199.034,4970 kkal/jam

Tabel B.9 Neraca Energi *Cooler* 1

Komponen	Masuk (kkal/jam)	Keluar (kkal/jam)
Q_{12}	186.890,8127	
Q_{14}		33.787,3535
Q_{cw}		199.034,4970
Q_{hw}	45931,0378	
Total	**232.821,8505**	**232.821,8505**

8. *Heater* 2

Fungsi : Menaikkan temperatur larutan KOH sebelum masuk kedalam reaktor.



Kondisi operasi:

- Tekanan : 1 atm
- Temperatur : 132 °C

  T_{in} : 60 °C = 333,15 K

  T_{out} : 132 °C = 405,15 K

  T_{steam} : 242 °C = 515,15 K

Keterangan:

Q_{17} : Panas umpan masuk

Q_{18} : Panas produk keluar

Q_S : Panas *steam* masuk

Q_C : Panas *condensate* keluar

➢ **Input**

Q_{17}

T_{in} : 30 °C = 303,15 K

T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	dT (K)	Q_{17} (kkal/jam)
KOH	258,5522	0,3584	5	463,2978
K_2CO_3	5,2766	0,1882	5	4,9649
H_2O	770,3801	0,9902	5	3.814,1520
Total	**1.034,2089**			**4.282,4147**

- **Output**
  - **Q_{18}**

T_{out} : 80 °C = 353,15 K

T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	dT (K)	Q_{18} (kkal/jam)
KOH	258,5522	0,3584	55	5.096,2753
K_2CO_3	5,2766	0,1882	55	54,6143
H_2O	770,3801	0,9902	55	41.955,6718
Total	**1.034,2089**	**0,5123**		**47.106,5614**

- **Kebutuhan *Steam***

$Q_{steam} = Q_{keluar} - Q_{masuk}$

Q_{steam} = 47.106,5614 – 4.282,4147 = 42.824,1467 kkal/jam

Media pemanas yang digunakan adalah *saturated steam* pada temperatur 242 ^oC, sehingga diperoleh data dari tabel F.1 *Saturated Steam* Halaman 669 Smith van ness sebagai berikut:

H_{liq} = 1047,2 kJ/kg = 250,1672 kkal/kg

H_{vap} = 2.802 kJ/kg = 669,3741 kkal/kg

λ_s = 1.754,8 kJ/kg = 419,2069 kkal/kg

$\Delta Q = m_s \times \lambda_s$

$$m_s = \frac{\Delta Q}{\lambda_s} = \frac{42.824,1467 \text{ kkal/jam}}{419,2069 \text{ kkal/kg}} = 102,1552 \text{ kg/jam}$$

Panas *steam* masuk

$Q_s = m_s \times H_{vap}$

Q_s = 102,1552 kg/jam x 669,3741 kkal/kg = 68.380,0200 kkal/jam

Panas *condensate* keluar

$Q_c = m_s \times H_{liquid}$

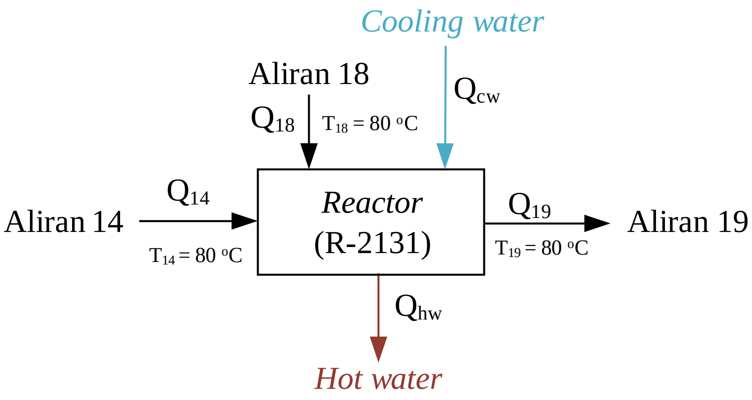
Q_c = 102,1552 kg/jam x 250,1672 kkal/kg = 25.555,8733 kkal/jam

Tabel B.10 Neraca Energi *Heater* 2

Komponen	Masuk (kkal/jam)	Keluar (kkal/jam)
Q_{17}	4.282,4147	
Q_{18}		47.106,5614
Qs	68.380,0200	
Q_C		25.555,8733
Total	**72.662,4346**	**72.662,4346**

9. Netralizer Reactor

Fungsi : Mereaksikan Asam lemak dengan Kalium hidroksida untuk menghasilkan sabun cair.



Kondisi operasi:

- Tekanan : 1 atm
- Temperatur : 80°C

  T_{in} : 80 °C = 352,15 K

  T_{out} : 80 °C = 353,15 K

  $T_{air\ pendingin}$: 28 °C = 298,15 K

➢ **Input**

- **Q_{14}**

  T_{in} : 80 °C = 353,15 K

  T_{ref} : 25 °C = 298,15 K

Komponen	Massa (kg/jam)	Cp (kkal/kg K)	dT (K)	Q_{14} (kkal/jam)
H_2O	0,0027	0,990	55	0,1483
$C_6H_{10}O$	0,1283	0,376	55	2,6548
$C_7H_{14}O$	0,0795	0,410	55	1,7919
$C_8H_{16}O$	0,3603	0,413	55	8,1916
$C_9H_{18}O$	0,0007	0,416	55	0,0161
$C_{29}H_{50}O_2$	6,7004	0,400	55	147,5439
$C_{12}H_{24}O_2$	1,5613	0,502	55	43,1349
$C_{14}H_{28}O_2$	11,5616	0,504	55	320,6667
$C_{16}H_{32}O_2$	493,8555	0,506	55	13.739,2408
$C_{18}H_{34}O_2$	397,4683	0,495	55	10.828,5981
$C_{27}H_{46}O$	10,7062	0,410	55	241,5308
$C_{18}H_{32}O_2$	110,2191	0,447	55	2.709,9972
$C_{18}H_{36}O_2$	48,4713	0,507	55	1.351,7920
$C_{30}H_{50}$	5,3604	0,411	55	121,0540
$C_{57}H_{104}O_6$	193,1806	0,402	55	4.270,9926
Total	**1.279,6562**			**33.787,3535**

- **Q_{18}**

  T_{in} : 80 °C = 353,15 K

  T_{ref} : 25 °C = 298,15 K

Komponen	massa (kg/jam)	Cp (kkal/kg K)	dT (K)	Q_{18} (kkal/jam)
H_2O	770,3801	0,9902	55,0000	41.955,6718
KOH	258,5522	0,3584	55,0000	5096,2753
K_2CO_3	5,2766	0,1882	55,0000	54,6143
Total	**1034,2089**			**47.106,5614**

➢ **Output**

- **Q_{19}**

  T_{out} : 50 °C = 323,15 K

  T_{ref} : 25 °C = 298,15 K

Komponen	Massa (kg/jam)	Cp (kkal/kg K)	dT (K)	Q_{19} (kkal/jam)
H_2O	841,3288	0,990	55	45.819,6088
$C_6H_{10}O$	0,1283	0,376	55	2,6548
$C_7H_{14}O$	0,0795	0,410	55	1,7919
$C_8H_{16}O$	0,3603	0,413	55	8,1916
$C_9H_{18}O$	0,0007	0,416	55	0,0161

$C_{29}H_{50}O_2$	6,7004	0,400	55	147,5439
$C_{12}H_{24}O_2$	0,0078	0,502	55	0,2164
$C_{14}H_{28}O_2$	0,0580	0,504	55	1,6086
$C_{16}H_{32}O_2$	2,5026	0,506	55	69,6243
$C_{18}H_{34}O_2$	1,9939	0,495	55	54,3215
$C_{27}H_{46}O$	10,7062	0,410	55	241,5308
$C_{18}H_{32}O_2$	0,5529	0,447	55	13,5947
$C_{18}H_{36}O_2$	0,2432	0,507	55	6,7812
$C_{30}H_{50}$	5,3604	0,411	55	121,0540
$C_{57}H_{104}O_6$	73,2992	0,402	55	1.620,5566
KOH	15,0485	0,358	55	296,6187
K_2CO_3	5,2766	0,188	55	54,6143
$C_{12}H_{23}O_2K$	1,8487	0,4317	55	43,8921
$C_{14}H_{27}O_2K$	13,4209	0,4408	55	325,3824
$C_{16}H_{31}O_2K$	564,2880	0,4482	55	13.910,1998
$C_{18}H_{35}O_2K$	54,6812	0,4543	55	1.366,2967
$C_{18}H_{33}O_2K$	578,9533	0,4436	55	14.126,7036
$C_{18}H_{31}O_2K$	124,5495	0,4008	55	2.745,4963
$C_3H_8O_3$	12,4764	0,3464	55	237,7123
Total	**2.313,8652**			**81.216,0112**

- **Panas Reaksi**

a. Menghitung Entalpi Reaksi Pada Keadaan Standar (ΔH_r° 25°C)

1. Reaksi 1

   $C_{12}H_{24}O_2$ = 0,12%

   Konversi reaksi = 99%

	$C_{12}H_{24}O_{2\,(l)}$ +	$KOH_{(aq)}$ →	$C_{12}H_{23}O_2K_{(l)}$ +	$H_2O_{(l)}$
M	: 0,00781	0,00781		
B	: 0,00777	0,00777	0,00777	0,00777
S	: 0,00004	0,00004	0,00777	0,00777

Berikut data entalpi komponen dalam keadaan standar (ΔH_f° 25°C)

Komponen	ΔH_f (kkal/kmol)	BM (kg/kmol)	m (kg/jam)	n (kmol/jam)
$C_{12}H_{24}O_2$	-169,478	200	1,56134	0,0078
KOH	-101,452	56	0,43718	0,0078
$C_{12}H_{23}O_2K$	-148,268	238	1,84868	0,0078
H_2O	-68,269	18	0,13982	0,0078

Panas reaksi standar masing-masing komponen pada suhu 25°C adalah

$\Delta H_r°$ 25°C = $\Delta H_f°$ produk - $\Delta H_f°$ reaktan

$\Delta H_r°$25°C = {(0,0078 kmol x (-148,268 kkal/kmol)) + (0,0078 kmol x (-68,269 kkal/kmol))} – {(0,0078 kmol x (-169,478 kkal/kmol)) + (0,0078 kmol x (-101,452 kkal/kmol))}

$\Delta H_r°$ 25°C = 0,4225 kkal/jam

2. Reaksi 2

$C_{14}H_{28}O_2$ = 0,90%

Konversi reaksi = 99%

	$C_{14}H_{28}O_{2\,(l)}$	+ $KOH_{(aq)}$	→ $C_{14}H_{27}O_2K_{(l)}$	+ $H_2O_{(l)}$
M	: 0,05071	0,05071		
B	: 0,05045	0,05045	0,05045	0,05045
S	: 0,00025	0,00025	0,05045	0,05045

Berikut data entalpi komponen dalam keadaan standar ($\Delta H_f°$ 25°C)

Komponen	ΔH_f (kkal/kmol)	BM (kg/kmol)	m (kg/jam)	n (kmol/jam)
$C_{14}H_{28}O_2$	-179,338	228	11,56161	0,0505
KOH	-101,452	56	2,83969	0,0505
$C_{14}H_{27}O_2K$	-158,128	266	13,42088	0,0505
H_2O	-68,269	18	0,90818	0,0505

Panas reaksi standar masing-masing komponen pada suhu 25°C adalah

$\Delta H_r°$ 25°C = $\Delta H_f°$ produk - $\Delta H_f°$ reaktan

$\Delta H_r°$25°C = {(0,0505 kmol x (-158,128 kkal/kmol)) + (0,0505 kmol x (-68,269 kkal/kmol))} – {(0,0505 kmol x (-179,338 kkal/kmol)) + (0,0505 kmol x (-101,452 kkal/kmol))}

$\Delta H_r°$ 25°C = 2,7443 kkal/jam

3. Reaksi 3

$C_{16}H_{32}O_2$ = 38,59%

Konversi reaksi = 99%

	$C_{16}H_{32}O_{2\,(l)}$ +	$KOH_{(aq)}$ →	$C_{16}H_{31}O_2K_{(l)}$ +	$H_2O_{(l)}$
M	: 1,92912	1,92912		
B	: 1,91935	1,91935	1,91935	1,91935
S	: 0,00978	0,00978	1,91935	1,91935

Berikut data entalpi komponen dalam keadaan standar (ΔH_f° 25°C)

Komponen	**ΔH_f (kkal/kmol)**	**BM (kg/kmol)**	**m (kg/jam)**	**n (kmol/jam)**
$C_{16}H_{32}O_2$	-189,197	256	493,85549	1,9293
KOH	-101,452	56	108,03089	1,9293
$C_{16}H_{31}O_2K$	-167,988	294	564,28804	1,9193
H_2O	-68,269	18	34,54825	1,9193

Panas reaksi standar masing-masing komponen pada suhu 25°C adalah

ΔH_r° 25°C = ΔH_f° produk - ΔH_f° reaktan

ΔH_r°25°C = {(1,9193 kmol x (-167,988 kkal/kmol)) + (1,9193 kmol x (-68,269 kkal/kmol))} – {(1,9293 kmol x (-189,197 kkal/kmol)) + (1,9293 kmol x (-101,452 kkal/kmol))}

ΔH_r° 25°C = 104,3979 kkal/jam

4. Reaksi 4

$C_{18}H_{36}O_2$ = 3,79%

Konversi reaksi = 99%

	$C_{18}H_{36}O_{2\,(l)}$ +	$KOH_{(aq)}$ →	$C_{18}H_{35}O_2K_{(l)}$ +	$H_2O_{(l)}$
M	: 0,17067	0,17067		
B	: 0,16982	0,16982	0,16982	0,16982
S	: 0,00086	0,00086	0,16982	0,16982

Berikut data entalpi komponen dalam keadaan standar ($\Delta H_f°$ 25°C)

Komponen	**ΔH_f (kkal/kmol)**	**BM (kg/kmol)**	**m (kg/jam)**	**n (kmol/jam)**
$C_{18}H_{36}O_2$	-199,057	284	48,47126	0,1698
KOH	-101,452	56	9,55771	0,1698
$C_{18}H_{35}O_2K$	-177,847	322	54,68116	0,1698
H_2O	-68,269	18	3,05671	0,1698

Panas reaksi standar masing-masing komponen pada suhu 25°C adalah

$\Delta H_r°$ 25°C = $\Delta H_f°$ produk - $\Delta H_f°$ reaktan

$\Delta H_r°$25°C = {(0,1698 kmol x (-177,847 kkal/kmol)) + (0,1698 kmol x (-68,269 kkal/kmol))} – {(0,1698 kmol x (-199,057 kkal/kmol)) + (0,1698 kmol x (-101,452 kkal/kmol))}

$\Delta H_r°$ 25°C = 9,2368 kkal/jam

5. Reaksi 5

$C_{18}H_{34}O_2$ = 31,06%

Konversi reaksi = 99%

	$C_{18}H_{34}O_{2\,(l)}$ +	$KOH_{(aq)}$ →	$C_{18}H_{33}O_2K_{(l)}$ +	$H_2O_{(l)}$
M	: 1,40946	1,40946		
B	: 1,40239	1,40239	1,40239	1,40239
S	: 0,00707	0,00707	1,40239	1,40239

Berikut data entalpi komponen dalam keadaan standar ($\Delta H_f°$ 25°C)

Komponen	**ΔH_f (kkal/kmol)**	**BM (kg/kmol)**	**m (kg/jam)**	**n (kmol/jam)**
$C_{18}H_{34}O_2$	-172,989	282	397,46830	1,4024
KOH	-101,452	56	78,92988	1,4024
$C_{18}H_{33}O_2K$	-151,779	320	448,76528	1,4024
H_2O	-68,269	18	25,24305	1,4024

Panas reaksi standar masing-masing komponen pada suhu 25°C adalah

$\Delta H_r°$ 25°C = $\Delta H_f°$ produk - $\Delta H_f°$ reaktan

$\Delta H_r°$25°C = {(1,4024 kmol x (-172,989 kkal/kmol)) + (1,4024 kmol x (-68,269 kkal/kmol))} – {(1,4024 kmol x (-151,779 kkal/kmol)) + (1,4024 kmol x -101,452 kkal/kmol))}

$\Delta H_r°$ 25°C = 76,2794 kkal/jam

6. Reaksi 6

$C_{18}H_{32}O_2$ = 8,61%

Konversi reaksi = 99%

	$C_{18}H_{32}O_{2\,(l)}$ +	$KOH_{(aq)}$ →	$C_{18}H_{31}O_2K_{(l)}$ +	$H_2O_{(l)}$
M	: 0,39364	0,39364		
B	: 0,39167	0,39167	0,39167	0,39167
S	: 0,00197	0,00197	0,39167	0,39167

Berikut data entalpi komponen dalam keadaan standar ($\Delta H_f°$ 25°C)

Komponen	**ΔH_f (kkal/kmol)**	**BM (kg/kmol)**	**m (kg/jam)**	**n (kmol/jam)**
$C_{18}H_{32}O_2$	-146,9213	280	110,21913	0,3917
KOH	-101,452	56	22,04383	0,3917
$C_{18}H_{31}O_2K$	-125,712	318	124,54949	0,3917
H_2O	-68,269	18	7,04997	0,3917

Panas reaksi standar masing-masing komponen pada suhu 25°C adalah

$\Delta H_r°$ 25°C = $\Delta H_f°$ produk - $\Delta H_f°$ reaktan

$\Delta H_r°$25°C = {(0,3917 kmol x (-125,712 kkal/kmol)) + (0,3917 kmol x (-68,269 kkal/kmol))} – {(0,3917 kmol x (-146,921 kkal/kmol)) + (0,3917 kmol x (-101,452 kkal/kmol))}

$\Delta H_r°$ 25°C = 21,3036 kkal/jam

7. Reaksi 7

$C_{57}H_{104}O_6$ = 15%

Konversi reaksi = 62%

	$C_{57}H_{104}O_{6\,(l)}$ +	$3KOH_{(aq)}$ →	$3C_{18}H_{31}O_2K_{(l)}$ +	$3H_8O_{3(l)}$
M	: 0,21853	0,65559		
B	: 0,13561	0,40684	0,40684	0,13561
S	: 0,08292	0,24875	0,40684	0,13561

Berikut data entalpi komponen dalam keadaan standar ($\Delta H_f°$ 25°C)

Komponen	ΔH_f (kkal/kmol)	BM (kg/kmol)	m (kg/jam)	n (kmol/jam)
$C_{57}H_{104}O_6$	-456,129	884	193,18062	0,1356
KOH	-304,357	56	36,71306	0,4068
$C_{18}H_{33}O_2K$	-455,338	320	130,18802	0,4068
$C_3H_8O_3$	-159,931	92	12,47635	0,1356

Panas reaksi standar masing-masing komponen pada suhu 25°C adalah

$\Delta H_r°$ 25°C = $\Delta H_f°$ produk - $\Delta H_f°$ reaktan

$\Delta H_r°$25°C = {(0,4068 kmol x (-455,338 kkal/kmol)) + (0,1356 kmol x (-159,931 kkal/kmol))} – {(0,1356 kmol x (-456,129 kkal/kmol)) + (0,4068 kmol x (-304,357 kkal/kmol))}

$\Delta H_r°$ 25°C = -21,2569 kkal/jam

b. Menghitung Entalpi Pada Kondisi Operasi

1. Reaksi 1

Reaksi berlangsung pada:

$T_{operasi}$ = 80 °C = 353,15 K

T_{ref} = 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	ΔT (K)	ΔH_f (80°C) reaktan (kkal/jam)	ΔH_f (80°C) produk (kkal/jam)
$C_{12}H_{24}O_2$	1,55351	0,5023	55	43,1349	-
KOH	0,43498	0,3584	55	8,6171	-
$C_{12}H_{23}O_2K$	1,84868	0,4317	55	-	43,8921
H_2O	0,13982	0,4170	55	-	3,2070
Total				**51,7520**	**47,0991**

ΔH_r 80°C = $\Delta H_r°$25°C (ΔH_f produk - ΔH_f reaktan)

= 0,4225 + (47,0991 - 51,7520) kkal/jam

= -3,9708 kkal/jam (Eksotermis)

2. Reaksi 2

Reaksi berlangsung pada:

$T_{operasi}$ = 80 °C = 353,15 K

T_{ref} = 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	ΔT (K)	ΔH_f (80°C) reaktan (kkal/jam)	ΔH_f (80°C) produk (kkal/jam)
$C_{14}H_{28}O_2$	11,50361	0,5023	55	320,6667	-
KOH	2,82545	0,3584	55	55,9727	-
$C_{14}H_{27}O_2K$	13,42088	0,4317	55	-	325,3824
H_2O	0,90818	0,4170	55	-	20,8311
Total				**376,6394**	**346,2134**

ΔH_r 80°C = ΔH_r°25°C (ΔH_f produk - ΔH_f reaktan)

= 2,7443 + (346,2134 – 376,6394) kkal/jam

= -25,7922 kkal/jam (Eksotermis)

3. Reaksi 3

Reaksi berlangsung pada:

$T_{operasi}$ = 80 °C = 353,15 K

T_{ref} = 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	ΔT (K)	ΔH_f (80°C) reaktan (kkal/jam)	ΔH_f (80°C) produk (kkal/jam)
$C_{16}H_{32}O_2$	491,35285	0,5023	55	13.739,2408	-
KOH	107,48344	0,3584	55	2.129,3769	-
$C_{16}H_{31}O_2K$	564,28804	0,4317	55	-	13.910,1998
H_2O	34,54825	0,4170	55	-	792,4387
Total				**15.868,6177**	**14.702,6385**

ΔH_r 80°C = ΔH_r°25°C (ΔH_f produk - ΔH_f reaktan)

= 104,3979 + (14.702,6385 – 15.868,6177) kkal/jam

= -981,1664 kkal/jam (Eksotermis)

4. Reaksi 4

Reaksi berlangsung pada:

$T_{operasi}$ = 80 °C = 353,15 K

T_{ref} = 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	ΔT (K)	ΔH_f (80°C) reaktan (kkal/jam)	ΔH_f (80°C) produk (kkal/jam)
$C_{18}H_{36}O_2$	48,22810	0,5023	55	1.351,7920	-
KOH	9,50977	0,3584	55	188,3903	-
$C_{18}H_{35}O_2K$	54,68116	0,4317	55	-	1.366,2967
H_2O	3,05671	0,4170	55	-	70,1123
Total				**1.540,1823**	**1.436,4090**

ΔH_r 80°C = ΔH_r°25°C (ΔH_f produk - ΔH_f reaktan)

= 9,2368 + (1.436,4090 – 1.540,1823) kkal/jam

= -86,8102 kkal/jam (Eksotermis)

5. Reaksi 5

Reaksi berlangsung pada:

$T_{operasi}$ = 80 °C = 353,15 K

T_{ref} = 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	ΔT (K)	ΔH_f (80°C) reaktan (kkal/jam)	ΔH_f (80°C) produk (kkal/jam)
$C_{18}H_{34}O_2$	395,47441	0,5023	55	10.828,5981	-
KOH	78,53392	0,3584	55	1.555,7722	-
$C_{18}H_{33}O_2K$	448,76528	0,4317	55	-	11.213,1226
H_2O	25,24305	0,4170	55	-	579,0038
Total				**12.384,3702**	**11.792,1264**

ΔH_r 80°C = ΔH_r°25°C (ΔH_f produk - ΔH_f reaktan)

= 76,2794 + (11.792,1264 – 12.384,3702) kkal/jam

= -453,8384 kkal/jam (Eksotermis)

6. Reaksi 6

Reaksi berlangsung pada:

$T_{operasi}$ = 80 °C = 353,15 K

T_{ref} = 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	ΔT (K)	ΔH_f (80°C) reaktan (kkal/jam)	ΔH_f (80°C) produk (kkal/jam)
$C_{18}H_{32}O_2$	109,66622	0,5023	55	2.709,9972	-
KOH	21,93324	0,3584	55	434,5018	-
$C_{18}H_{31}O_2K$	124,54949	0,4317	55	-	2.745,4963
H_2O	7,04997	0,4170	55	-	161,7063
Total				**3.144,4989**	**2.907,2026**

ΔH_r 80°C = ΔH_r°25°C (ΔH_f produk - ΔH_f reaktan)

= 21,3036 + (2.907,2026 – 3.144,4989) kkal/jam

= -200,2184 kkal/jam (Eksotermis)

7. Reaksi 7

Reaksi berlangsung pada:

$T_{operasi}$ = 80 °C = 353,15 K

T_{ref} = 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	ΔT (K)	ΔH_f (80°C) reaktan (kkal/jam)	ΔH_f (80°C) produk (kkal/jam)
$C_{57}H_{104}O_6$	119,88147	0,5023	55	4.270,9926	-
KOH	22,78290	0,3584	55	723,6443	-
$C_{18}H_{33}O_2K$	130,18802	0,4317	55	-	3.176,6424
$C_3H_8O_3$	12,47635	0,4170	55	-	237,7123
Total				**4.994,6369**	**3.414,3547**

ΔH_r 80°C = ΔH_r°25°C (ΔH_f produk - ΔH_f reaktan)

= -21,2569 + (3.414,3547 – 4.994,6369) kkal/jam

= 293,5922 kkal/jam (Endotermis)

ΔH_r 80°C Total = -3,9708 + (-25,7992) + (-981,1664) + (-86,8102) +

(-453,8384) + (-200,2184) + (293,5922)) kkal/jam

= -1.458,2042 kkal/jam (Eksotermis)

QR = - ΔH_r 80°C Total

= 1.458,2042 kkal/jam

c. Beban Pendingin

Proses netralisasi asam lemak dengan kalium hidroksida pada temperatur 80°C, karena reaksi netralisasi berlangsung secara eksotermis sehingga dibutuhkan pendingin, beban pendingin adalah:

$Q_{masuk} = Q_{keluar} + Q_{CW}$

$Q_{14} + Q_{18} + QR = Q_{19} + Q_{CW}$

(33.787,3535 + 47.106,5614 + 1.458,2042) kkal/jam = 81.216,0112 kkal/jam + Q_{CW}

82.352,1190 kkal/jam = 81.216,0112 kkal/jam + Q_{CW}

Q_{CW} = 1.136,1078 kkal/jam

$T_{\text{air pendingin}}$ = 301,15 K

$T_{\text{sisa pendingin}}$ = 311,15 K

Jumlah air pendingin yang dibutuhkan,

$Q = m \times Cp \times \Delta T$

$$m = \frac{1.136,1078 \text{ kkal/jam}}{1 \text{ kkal/kg.K} \times (311,15 \text{ K} - 301,15 \text{ K})} = 113,6108 \text{ kg}$$

Panas sensibel air pendingin masuk ($Q_{cw\ in}$):

$Q_{cw\ in} = m \times Cp \times \Delta T$

$Q_{cw\ in}$ = 113,6108 kg/jam x 1 kkal/kg.C x (28 – 25) C

$Q_{cw\ in}$ = 340,8323 kkal/jam

Panas sensibel air panas keluar ($Q_{hw\ out}$):

$Q_{hw\ out} = m \times Cp \times \Delta T$

$Q_{hw\ out}$ = 113,6108 kg/jam x 1 kkal/kg.C x (38 – 25) C

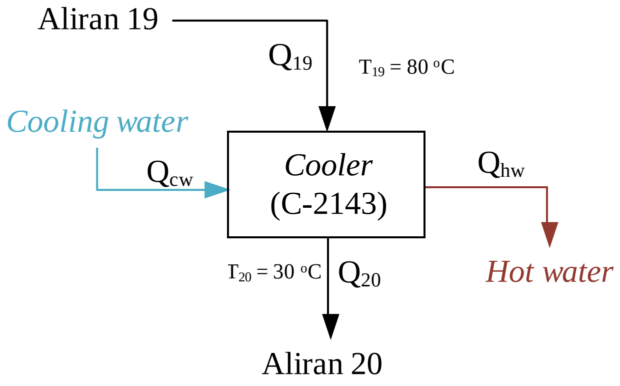
$Q_{hw\ out}$ = 1.476,9401 kkal/jam

Tabel B.11 Neraca Energi *Netralizer* Reaktor

Komponen	Masuk (kkal/jam)	Keluar (kkal/jam)
Q_{14}	33.787,3535	
Q_{18}	47.106,5614	
Q_{19}		81.216,0112
Q_R	1.458,2042	
Q_W	340,8323	1.476,9401
Total	**82.692,9514**	**82.692,9514**

10. Cooler 2

Fungsi : Menurunkan temperatur sabun cair yang dihasilkan dari reaktor.



Kondisi operasi:

- Tekanan : 1 atm
- Temperatur : 30 °C

T_{in} : 80 °C = 353,15 K

T_{out} : 30 °C = 303,15 K

$T_{cooling\ water}$: 28 °C = 301,15 K

Keterangan:

Q_{19} : Panas liquid masuk

Q_{20} : Panas liquid keluar

Q_{cw} : Panas air pendingin masuk

Q_{hw} : Panas air pendingin keluar

Q_C : Panas yang diserap *cooler*, $Q_C = Q_{14} - Q_{12}$

➢ **Input**

Q_{19}

T_{in} : 80 °C = 353,15 K

T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	dT (K)	Q_{19} (kkal/jam)
H_2O	841,3288	0,9902	55	45.819,6088
$C_6H_{10}O$	0,1283	0,3763	55	2,6548
$C_7H_{14}O$	0,0795	0,4097	55	1,7919
$C_8H_{16}O$	0,3603	0,4134	55	8,1916

$C_9H_{18}O$	0,0007	0,4164	55	0,0161
$C_{29}H_{50}O_2$	6,7004	0,4004	55	147,5439
$C_{12}H_{24}O_2$	0,0078	0,5023	55	0,2164
$C_{14}H_{28}O_2$	0,0580	0,5043	55	1,6086
$C_{16}H_{32}O_2$	2,5026	0,5058	55	69,6243
$C_{18}H_{34}O_2$	1,9939	0,4953	55	54,3215
$C_{27}H_{46}O$	10,7062	0,4102	55	241,5308
$C_{18}H_{32}O_2$	0,5529	0,4470	55	13,5947
$C_{18}H_{36}O_2$	0,2432	0,5071	55	6,7812
$C_{30}H_{50}$	5,3604	0,4106	55	121,0540
$C_{57}H_{104}O_6$	73,2992	0,4020	55	1.620,5566
KOH	15,0485	0,3584	55	296,6187
K_2CO_3	5,2766	0,1882	55	54,6143
$C_{12}H_{23}O_2K$	1,8487	0,4317	55	43,8921
$C_{14}H_{27}O_2K$	13,4209	0,4408	55	325,3824
$C_{16}H_{31}O_2K$	564,2880	0,4482	55	13.910,1998
$C_{18}H_{35}O_2K$	54,6812	0,4543	55	1.366,2967
$C_{18}H_{33}O_2K$	578,9533	0,4436	55	14.126,7036
$C_{18}H_{31}O_2K$	124,5495	0,4008	55	2.745,4963
$C_3H_8O_3$	12,4764	0,3464	55	237,7123
Total	**2.313,8652**			**81.216,0112**

- **Output**
  - **Q_{20}**

T_{out} : 30 °C = 303,15 K

T_{ref} : 25 °C = 298,15 K

Komponen	m (kg/jam)	Cp (kkal/kg.K)	dT (K)	Q_{20} (kkal/jam)
H_2O	841,3288	0,9902	5	4.165,4190
$C_6H_{10}O$	0,1283	0,3763	5	0,2413
$C_7H_{14}O$	0,0795	0,4097	5	0,1629
$C_8H_{16}O$	0,3603	0,4134	5	0,7447
$C_9H_{18}O$	0,0007	0,4164	5	0,0015
$C_{29}H_{50}O_2$	6,7004	0,4004	5	13,4131
$C_{12}H_{24}O_2$	0,0078	0,5023	5	0,0197
$C_{14}H_{28}O_2$	0,0580	0,5043	5	0,1462
$C_{16}H_{32}O_2$	2,5026	0,5058	5	6,3295
$C_{18}H_{34}O_2$	1,9939	0,4953	5	4,9383
$C_{27}H_{46}O$	10,7062	0,4102	5	21,9573
$C_{18}H_{32}O_2$	0,5529	0,4470	5	1,2359

$C_{18}H_{36}O_2$	0,2432	0,5071	5	0,6165
$C_{30}H_{50}$	5,3604	0,4106	5	11,0049
$C_{57}H_{104}O_6$	73,2992	0,4020	5	147,3233
KOH	15,0485	0,3584	5	26,9653
K_2CO_3	5,2766	0,1882	5	4,9649
$C_{12}H_{23}O_2K$	1,8487	0,4317	5	3,9902
$C_{14}H_{27}O_2K$	13,4209	0,4408	5	29,5802
$C_{16}H_{31}O_2K$	564,2880	0,4482	5	1.264,5636
$C_{18}H_{35}O_2K$	54,6812	0,4543	5	124,2088
$C_{18}H_{33}O_2K$	578,9533	0,4436	5	1.284,2458
$C_{18}H_{31}O_2K$	124,5495	0,4008	5	249,5906
$C_3H_8O_3$	12,4764	0,3464	5	21,6102
Total	**2.313,8652**			**7.383,2737**

- **Beban Panas**

  $\Delta Q = Q_{20} - Q_{19}$

  ΔQ = 81.216,0112 kkal/jam - 7.383,2737 kkal/jam

  ΔQ = 81.216,0112 kkal/jam

- **Kebutuhan Pendingin**

  Jumlah air pendingin yang dibutuhkan

  $$m = \frac{Q}{Cp \times \Delta T} = \frac{81.216{,}0112 \text{ kkal/jam}}{1 \text{ kkal/kg.C} \times (38 - 28) \text{ C}} = 7.383{,}2737 \text{ kg/jam}$$

  Panas sensibel air pendingin masuk ($Q_{cw\ in}$):

  $Q_{cw\ in} = m \times Cp \times \Delta T$

  $Q_{cw\ in}$ = 7.383,2737 kg/jam x 1 kkal/kg.C x (28 – 25) C

  $Q_{cw\ in}$ = 22.149,8212 kkal/jam

  Panas sensibel air panas keluar ($Q_{hw\ out}$):

  $Q_{hw\ out} = m \times Cp \times \Delta T$

  $Q_{hw\ out}$ = 7.383,2737 kg/jam x 1 kkal/kg.C x (38 – 25) C

  $Q_{hw\ out}$ = 95.982,5587 kkal/jam

Tabel B.12 Neraca Energi *Cooler* 2

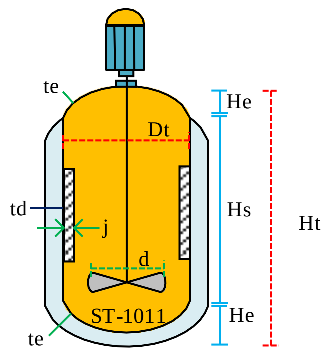
Panas	**Masuk (kkal/jam)**	**Keluar (kkal/jam)**
Q_{19}	81.216,0112	
Q_{20}		7.383,2737
Q_{cw}	22.149,8212	
Q_{hw}		95.982,5587
Total	**103.365,8325**	**103.365,8325**

LAMPIRAN C. SPESIFIKASI PERALATAN

A. Spesifikasi Peralatan Proses

1) *Storage Tank Palm Fatty Acid Distillate* (ST-1011)

Fungsi	: Tempat menyimpan dan mencairkan *palm fatty acid distillate*
Tipe	: Silinder vertikal dengan alas dan tutup *elipsoidal*
Bahan konstruksi	: *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*
Jumlah	: 1 unit
Sifat bahan	: Tidak volatil dan korosif pada baja ringan
Fasa	: Cair



Gambar LC-1. *Storage Tank PFAD*

Data:

• Laju alir umpan	: 1.341,531 kg/jam	: 2.957,5392 lb/jam
• Densitas campuran	: 879,8449 kg/m^3	: 54,9287 lb/ft^3
• Tekanan	: 1 atm	
• Viskositas Campuran	: 8,2309 cP	: 0,0055 lb/ft.s
• Lama Penyimpanan	: 3 Hari	: 72 jam

1. Kapasitas Tangki

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

$$V_p = \frac{1.341,531 \text{ kg/jam} \times 72 \text{ jam}}{879,8449 \text{ kg/m}^3}$$

V_p = 109,7810 m^3

= 3.876,8062 ft^3

= 6.699.247,6401 in^3

= 29.001,0663 gal

Dengan Mempertimbangkan faktor keamanan 20 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

V_p = 0,8 V_t

$$V_t = \frac{V_p}{0,8}$$

$$V_t = \frac{109,7810 \text{ m}^3}{0,8}$$

V_t = 137,2263 m^3

= 4.846,0096 ft^3

= 8.374.062,60013 in^3

= 36.251,3461 gal

2. Dimensi Tangki

a. Volume Silinder

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

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

V_s = 1,1775 D_t^3

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^{2} \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0{,}1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + 2\ V_e$

$V_t = 1{,}1775\ D_t^3 + 2\ (0{,}1308\ D_t^3)$

$V_t = 1{,}4391\ D_t^3$

$$D_t^3 = \frac{V_t}{1{,}4391}$$

$$D_t^3 = \frac{137{,}2263\ m^3}{1{,}4391}$$

$$D_t = \sqrt[3]{\frac{137{,}2263\ m^3}{1{,}4391}}$$

$D_t = 4{,}5679$ m

= 14,9827 ft

= 179,838 in

d. Tinggi Silinder

$H_s = 1{,}5\ D_t$

$H_s = 1{,}5 \times 4{,}5679$ m

$H_s = 6{,}8518$ m

= 22,4739 ft

= 269,7554 in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 4{,}5679$ m

$H_e = 1{,}1420$ m

$= 3{,}7458$ ft

$= 44{,}9605$ in

f. Tinggi Tangki

$H_t = H_s + (2\ H_e)$

$H_t = 6{,}8518 \text{ m} + (2 \times 1{,}1420 \text{ m})$

$H_t = 9{,}1358$ m

g. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s + (2\ H_e))}{V_t}$$

$$H_c = \frac{109{,}7810 \text{ m}^3 \times (6{,}8518 \text{ m} + (2 \times 1{,}1420 \text{ m}))}{137{,}2263 \text{ m}^3}$$

$H_c = 7{,}386$ m

$= 23{,}9722$ ft

$= 287{,}7396$ in

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

$P_c = 879{,}8449 \text{ kg/m}^3 \times 9{,}81 \text{ m/s}^2 \times 7{,}3086 \text{ m}$

$P_c = 63.082{,}5618 \text{ kg.m/s}^2$

$= 0{,}6119$ atm

$= 8{,}9924$ psi

i. Tekanan Desain

$P_d = P_{op} + P_c$

P_d = 1 atm + 0,6119 atm

P_d = 1,6119 atm

= 23,6949 psi

P_d = 23,6949 psi

R = 89,9190 in

S = 18700 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{23,6949 \text{ psi} \times 89,9190 \text{ in}}{18700 \text{ psi} \times 0,85 - 0,6 \times 23,6949 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,3342 in

= 0,0085 m

= 0,0279 ft

= 8,4887 mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0,2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{23,6949 \text{ psi} \times 179,838 \text{ in}}{2 \times 18700 \text{ psi} \times 0,85 - 0,2 \times 23,6949 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,3341 in

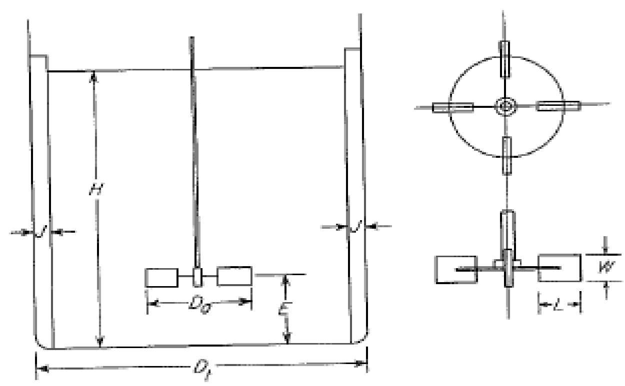
= 0,0085 m

= 0,0279 ft

= 8,4887 mm

3. Desain Pengaduk

Viskositas umpan < 4000 cP, maka dipilih *propeller* berdaun tiga (Kecepatan 1800 rpm) (*Walas - Selection Design & Chemical Process Equipment ed 1st, Page 288*).



Gambar LC-2. Desain Pengaduk *Storage Tank PFAD*

a. Diameter Pengaduk

$$d = \frac{D_t}{3}$$

$$d = \frac{4,5679 \text{ m}}{3}$$

d = 1,5226 m

= 4,9941 ft

b. Panjang Daun Pengaduk

$$L = \frac{d}{4}$$

$$L = \frac{1,5226 \text{ m}}{4}$$

L = 0,3807 m

= 1,2487 ft

c. Lebar Daun Pengaduk

$$W = \frac{d}{5}$$

$$W = \frac{1,5226 \text{ m}}{5}$$

W = 0,3045 m

= 0,9988 ft

d. Tinggi Pengaduk Dari Dasar Tangki

$$E = \frac{D_t}{3}$$

$$E = \frac{4,5679 \text{ m}}{3}$$

E = 1,5226 m

= 4,9941 ft

e. Lebar *Baffle*

$$J = \frac{D_t}{12}$$

$$J = \frac{4,5679 \text{ m}}{12}$$

J = 0,3807 m

= 1,2487 ft

f. Kecepatan Putar Pengaduk

Berdasarkan persamaan 6-18 *Robert Treyball-Mass Transfer Operation,* kecepatan putar pengaduk dapat dihitung dengan persamaan berikut.

Dengan $g_c = 32,2\ ft/s^2$

σ = 72,75 dyn/cm (*Mc.cabe – Unit Operation Of Chemical Engineering 5th Page 274*).

= 0,0537 lb/ft

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

$$\frac{N_d}{\left(\frac{0,0537\ lb/ft \times 32,2\ ft/s^2}{54,9287\ lb/ft^3}\right)^{0,25}} = 1,22 + 1,25\left(\frac{14,9827\ ft}{4,9941\ ft}\right)$$

$$N_d = 0,5606\ rps$$

g. Daya Pengadukan

Berdasarkan persamaan 9-17 *Mc.cabe – Unit Operation Of Chemical Engineering 5^{t},* bilangan *reynold* dapat dihitung dengan persamaan berikut.

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

$$N_{Re} = \frac{54,9287\ lb/ft^3 \times 0,5606\ rps \times (4,9941\ ft)^2}{0,0150\ lb/ft.s}$$

N_{Re} = 139.638,1843

Karena Nre > 10.000, maka berdasarkan persamaan 9.24 *Mc.cabe – Unit Operation Of Chemical Engineering 5^{t}*, daya pengadukan menggunakan dapat dihitung dengan persamaan berikut.

Dengan K_T = 0,87 (*Mc. Cabe & Smith - Unit Operations Of Chemical Engineering 5th, Page 254*)

$$P = \frac{K_T N^3 D_a^5 \rho}{g_c}$$

$$P = \frac{0,87 \times (0,5606 \text{ rps})^3 \times (4,9941 \text{ ft})^5 \times 54,9287 \text{ lb/ft}^3}{32,2 \text{ ft/s}^2}$$

P = 812,2845 ft.lbf/s

P = 1,4769 HP

h. Daya Motor

Efisiensi Motor = 80%

$$\text{Daya Motor} = \frac{1,4769 \text{ HP}}{80\%}$$

Daya Motor = 1,8461 HP

≈ 2 HP

4. Desain Pemanas

Data:

- Temperatur Umpan : 30 °C, : 86 °F
- Temperatur Steam : 242 °C, : 467,6 °F
  - Densitas Steam : 2,6690 kg/m^3 : 0,1666 lb/ft^3 (*engineering toolbox.com*)
- Massa Steam : 46,0039 kg/jam : 101,4202 lb/jam
- Q : 19.285,1442 kkal/jam : 76.479,0964 btu/jam
- ΔT : 381,6 °F

Karena massa steam lebih kecil dari massa umpan, maka digunakan *jacket.*

a. Luas Permukaan Perpindahan Panas

$$A = \frac{Q}{U_d \times \Delta T}$$

Dengan U_d = 400 W/m^2C Engineeringpage.com

$= 70,44 \text{ Btu/ft}^2 \text{ F hr}$

$$A = \frac{76.479,0964 \text{ btu/hr}}{70,44 \text{ Btu/ft}^2 \text{ F hr} \times 381,6\ ^oF}$$

$= 2,8452 \text{ ft}^2$

b. Tinggi *Jacket*

Asumsi jarak *jacket* : 5 in : 0,1270 m

$H_j = H_c + t_e$ + Jarak jacket

H_j = 287,7396 in + 0,3341 in + 5 in

H_j = 293,0737 in

= 7,4441 m

= 24,4166 ft

c. Diameter *Jacket*

- Diameter Tangki

  $D_r = D_t + (2 \times t_d)$

  D_r = 179,8380 in + (2 × 0,3342 in)

  D_r = 180,5064 in

  = 4,5849 m

  = 15,0385 ft

- Diameter Luar *Jacket*

  $D_j = D_r$ + (2 × jarak *jacket*)

  D_j = 180,5064 in + (2 × 5 in)

  D_j = 190,5064 in

  = 4,8389 m

  = 15,8716 ft

d. Tekanan Hidrostatik Pada *Jacket*

$P_h = \rho \times g \times H_c$

P_h = 2,6690 kg/m^3× 9,81 m/s^2 × 7,3086 m

P_h = 191,3603 kg.m/s^2

= 0,0019 atm

= 0,0279 psi

e. Tekanan Desain

$P_d = P_{op} + P_h$

P_d = 1 atm + 0,0019 atm

P_d = 1,0019 atm

= 14,7279 psi

f. Tebal Dinding *Jacket*

$t_{dj} = D_j - D_r$

t_{dj} = 4,8389 m - 4,5849 m

t_{dj} = 0,2540 m

g. Volume *Steam*

$$V_s = \frac{Massa_{steam}}{Densitas_{steam}}$$

$$V_s = \frac{46{,}0039 \text{ kg/jam}}{2{,}6690 \text{ kg/m}^3}$$

V_s= 17,2364 m^3/jam

2) *Preheater* (HE-1021)

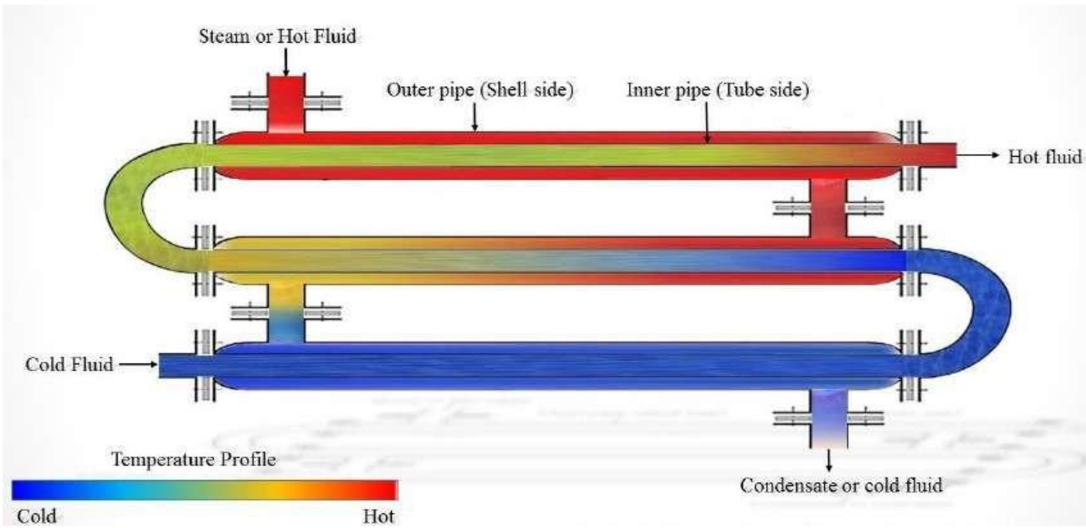
Fungsi : Untuk memanaskan PFAD sebelum masuk ke dalam *Deodorizer*

Tipe : *Double Pipe*

Bahan konstruksi : *Dupllex Stainless steel* Tipe-2205

Jumlah : 1 unit

Fasa : Cair



Gambar LC-3. *Preheater*

Data:

- Laju alir *hot fluid (Steam)* : 110,2922 kg/jam : 243,1502 lb/jam
- Laju alir *cold fluid* (PFAD) : 1.341,5322 kg/jam : 2.957,5419 lb/jam
- Q : 46.235,2658 kkal/jam : 183.461,5347 btu/jam
- Tekanan : 1 atm
- T_1 : 242 ^oC : 467,6 ^oF
- T_2 : 242 ^oC : 467,6 ^oF
- t_1 : 60 ^oC : 140 ^oF
- t_2 : 132 ^oC : 269,6 ^oF

1. Menentukan Jenis *Heater*

a. Menghitung LMTD

Hot fluid		***Cold Fluid***	***Difference***	
467,6	***High Temperatur***	269,6	198	Δt_2
467,6	***Low Temperatur***	140	327,6	Δt_1
			129,6	$\Delta t_2 - \Delta t_1$

$$LMTD = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln\left(\frac{T_1 - t_2}{T_2 - t_1}\right)}$$ DQ Kern, Pers 6.17 hal 117

$$LMTD = \frac{(467{,}6\ °F - 269{,}6\ °F) - (467{,}6\ °F - 140\ °F)}{\ln\left(\frac{467{,}6\ °F - 269{,}6\ °F}{467{,}6\ °F - 140\ °F}\right)}$$

$= 257{,}3982\ °F$

b. Luas Area Perpindahan Panas

Diketahui viskositas *cold fluid* : 8,2309 cP

Berdasarkan *Table 8 - DQ Kern Page 840,* diperoleh :

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¶

Maka dipilih U_d = 30 Btu/jam ft^2 °F

Maka,

$$A = \frac{Q}{U_d \times LMTD}$$ DQ. Kern Pers 7.42 Hal 144

$$A = \frac{183.461{,}5347\ btu/jam}{30\ Btu/jam\ ft^2\ °F \times 257{,}3982\ °F}$$

A = 23,7585 ft^2

Karena nilai A < 200 ft^2 maka tipe *heat exchanger* yang digunakan adalah *double pipe* (*DQ Kern Page 103*)

2. Pemilihan Ukuran *Double Pipe*

Berdasarkan *Table 6.2 DQ. Kern Page 110* maka dipilih ukuran *double pipe* berikut ini.

	Outer pipe	***Inner Pipe***	**Satuan**
IPS	3	2	In
Sch	40	40	
OD	3,5	2,38	In
ID	3,068	2,067	In
a''	0,917	0,622	ft^2/ft

3. Menentukan *caloric temperature*

$T_{av} = \frac{T_1 + T_2}{2}$ DQ.Kern Hal 113

$T_{av} = \frac{467{,}6\ °F + 467{,}6\ °F}{2}$

$= 467{,}6\ °F$

$t_{av} = \frac{t_1 + t_2}{2}$ DQ.Kern Hal 113

$t_{av} = \frac{140\ °F + 269{,}6\ °F}{2}$

$= 205\ °F$

<table>
<tr><th>Annulus (Steam)</th><th>Inner Pipe (PFAD)</th></tr>
<tr><td>4. Flow area
$a_a = \frac{\pi(D_2^2 - D_1^2)}{4}$ DQ. Kern Pers 6.3
$a_a = \frac{3{,}14\ ((0{,}2557\ ft)^2 - (0{,}1983\ ft)^2)}{4}$
$= 0{,}0205\ ft^2$
Equivalent diameter
$D_e = \frac{(D_2^2 - D_1^2)}{D_1}$ DQ. Kern Hal 111
$D_e = \frac{(0{,}2557\ ft)^2 - (0{,}1983\ ft)^2}{0{,}1983\ ft}$
$= 0{,}1314\ ft$

5. Laju alir massa
$G_a = \frac{W}{a_a}$ DQ. Kern Hal 114
$G_a = \frac{243{,}1502\ lb/jam}{0{,}0205\ ft^2}$
$= 11.860{,}9854\ lb/jam\ ft^2$

6. Bilangan Reynold
$T_{av} = 467{,}6\ °F$
μ steam = 0,017 cP
= 0,0411 lb/ft jam
DQ. Kern Hal 825</td>
<td>4. Flow area
$a_p = \frac{\pi(D^2)}{4}$ DQ. Kern Hal 111
$a_p = \frac{3{,}14\ ((0{,}1723\ ft)^2)}{4}$
$= 0{,}1753\ ft^2$

5. Laju alir massa
$G_p = \frac{W}{a_p}$ DQ. Kern Hal 114
$G_p = \frac{2.957{,}5419\ lb/jam}{0{,}1353\ ft^2}$
$= 21.859{,}1419\ lb/jam\ ft^2$

6. Bilangan Reynold
$T_{av} = 205\ °F$
μ PFAD = 4 cP
= 9,6768 lb/ft jam
DQ. Kern Hal 823</td></tr>
</table>

Water	8.0	16.0
Xenon	9.3	23.0

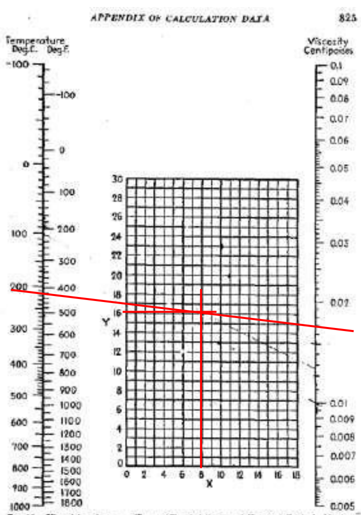


FIG. 15. Viscosities of gases. (Perry, "Chemical Engineers' Handbook," 3d ed., McGraw-Hill Book Company, Inc., New York, 1950.)

$$R_{ea} = \left(\frac{D_e \times G_a}{\mu}\right) \quad \text{DQ. Kern Hal 114}$$

$$R_{ea} = \left(\frac{0{,}1314 \text{ ft} \times 11.860{,}9854 \text{ lb/jam ft}^2}{0{,}0411 \text{ lb/ft jam}}\right)$$

$$= 37.920{,}5227$$

7. h_o

Steam yang mengalami perubahan fasa tanpa perubahan suhu maka $h_i = h_o = h_{io}$ (DQ. Kern Hal 163-164)

Maka, h_o = 1500 btu/hr ft^2 °F

	Sp gr at 300°F	X	Y
Lauric	0.792	10.1	23.1
Oleic	0.799	10.0	25.2
Palmitic	0.786	9.2	25.9
Stearic	0.789	10.5	25.5

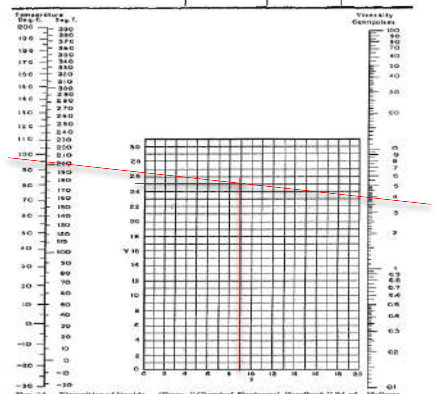


FIG. 14. Viscosities of liquids. (Perry, "Chemical Engineers' Handbook," 3d ed., McGraw-

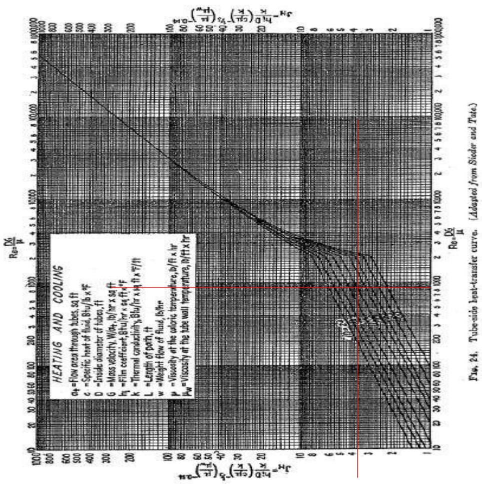
$$R_{ep} = \left(\frac{D \times G_p}{\mu}\right) \quad \text{DQ. Kern Hal 114}$$

$$R_{ep} = \left(\frac{0{,}1723 \text{ ft} \times 21.859{,}1419 \text{ lb/jam ft}^2}{9{,}6768 \text{ lb/ft jam}}\right)$$

$$= 941{,}5825$$

7. jH

jH = 3,8 DQ. Kern Hal 834



8. Konduktivitas dan kapasitas panas

Pada t_{av}= 205 °F

c = 0,653 btu/lb °F

k = 0,0835 btu/(hr)(ft^2)(°F)

DQ. Kern Hal 800

$$\left(\frac{c\ \mu}{k}\right)^{1/3} = \left(\frac{0{,}653\ \frac{btu}{lb\ °F} \times 9{,}6768\ \frac{lb}{hr\ ft}}{0{,}0835\ \frac{Btu}{(hr)\ (ft^2)(°F/ft)}}\right)^{\frac{1}{3}}$$

= 4,2298 ft

9. h_i

$$h_i = jH \frac{k}{D} \left(\frac{c\ \mu}{k}\right)^{\frac{1}{3}} \left(\frac{\mu}{\mu_w}\right)^{0,14}$$ pers 6.15a DQ Kern

$$h_i = (3{,}8) \frac{0{,}0835 \frac{btu}{(hr)\ (ft^2)(°F/ft)}}{0{,}1723\ ft} (4{,}2298\ ft)(1)$$

= 7,7894 btu/(hr)(ft^2)(°F)

10. Koreksi h_i

$$h_{io} = h_i \frac{ID}{OD}$$ pers 6.15 DQ Kern

$$h_{io} = 0{,}0835 \frac{btu}{(hr)\ (ft^2)(°F)} \frac{0{,}1723\ ft}{0{,}1983\ ft}$$

= 6,7681 btu/(hr)(ft^2)(°F)

Temperatur Dinding

$$t_w = t_{avg} + \frac{h_o}{h_{io} + h_o} \times (T_{avg} - t_{avg})$$

$$t_w = 205\ °F + \frac{1500\ btu/hr\ ft^2\ °F}{(6{,}7681 + 1500)\ btu/(hr)(ft^2)(°F)} \times (467{,}6 - 205)°F$$

	$= 466,4205\ °F$ Pada $t_w = 466,4205\ °F$ $\mu = 1,2$ lb/ft jam Maka, $\phi_p = \left(\frac{\mu}{\mu_w}\right)^{0,14}$ $\phi_p = \left(\frac{9,6768 \text{ lb/ft jam}}{1,2 \text{ lb/ft jam}}\right)^{0,14}$ $= 1,3394$ h_{io} sebenarnya = 6,7681 btu/(hr)(ft²)(°F) × 1,3394 $= 9,0652$ btu/(hr)(ft²)(°F)

11. Clean overall coefficient

$$U_c = \frac{h_{io} \times h_o}{h_{io} + h_o} \quad \text{Pers 6.7 DQ Kern}$$

$$U_c = \frac{9,0652 \frac{btu}{hr\ ft^2 °F} \times 1500 \frac{btu}{hr\ ft^2 °F}}{9,0652 \frac{btu}{hr\ ft^2 °F} + 1500 \frac{btu}{hr\ ft^2 °F}} = 9,0102 \frac{btu}{hr\ ft^2 °F}$$

12. Design overall coefficient

$$\frac{1}{U_d} = \frac{1}{U_c} + R_d \quad \text{Pers 6.10 DQ Kern}$$

$$\frac{1}{U_d} = \frac{1}{9,0102 \frac{btu}{hr\ ft^2 °F}} + 0,001\ ft^2\ hr\ °F/btu$$

$$U_d = 8,9286 \frac{btu}{hr\ ft^2 °F}$$

13. Surface area required

$$A = \frac{Q}{U_d \times LMTD}$$ DQ. Kern Pers 7.42 Hal 144

$$A = \frac{183.461{,}5347 \text{ btu/jam}}{8{,}9286 \text{ btu/jam ft}^2 \text{ °F} \times 257{,}3982 \text{ °F}}$$

$A = 79{,}8282 \text{ ft}^2$

14. Menghitung jumlah *hairpin*

Required length $= \frac{A}{a''}$

Required length $= \frac{79{,}8282 \text{ ft}^2}{0{,}622 \text{ ft}^2/\text{ft}}$

Required length = 128,3412 ft

Digunakan Panjang pipa untuk *double pipe heat exchanger* : 20 ft

1 *hairpin* terdiri dari 2 pipa, maka jumlah *hairpin* yang diperlukan adalah :

Hairpin $= \frac{L}{2 \times L_H}$

Hairpin $= \frac{128{,}3412 \text{ ft}}{2 \times 20 \text{ ft}}$

Hairpin = 3,2085

≈ 4

Koreksi Panjang pipa

L koreksi = 2 × L *Hairpin* × Banyak *Hairpin*

L koreksi = 2 × 20 ft × 4

L koreksi = 160 ft

15. Actual design overall coefficient

actual surface = *required length* × a''

actual surface = 160 ft × 0,622 ft^2/ft = 99,52 ft^2

$$U_d\ actual = \frac{Q}{A \times LMTD}$$

$$U_d\ actual = \frac{183.461,5347\ \text{btu/jam}}{99,52\ ft^2 \times 257,3982\ °F}$$

U_d *actual* = 7,1619 btu/jam ft^2 °F

Asumsi benar karena U_d *actual* < U_d desain

R_d sebenarnya

$$R_d = \frac{U_c - U_d}{U_c \times U_d}$$

$$R_d = \frac{9,0107\ \text{btu/jam}\ ft^2\ °F - 7,1619\ \text{btu/jam}\ ft^2\ °F}{9,0107\ \text{btu/jam}\ ft^2\ °F \times 7,1619\ \text{btu/jam}\ ft^2\ °F}$$

R_d = 0,0286 ft^2 jam °F/btu

R_d yang diperlukan = 0,001 ft^2 jam °F/btu

R_d sebenarnya > R_d yang diperlukan (memenuhi)

16. Pressure drop

Annulus (Steam)	***Inner Pipe (PFAD)***
1. $D_e' = D_2 - D_1$ Pers 6.4 DQ Kern D_e' = 0,2557 ft - 0,1983 ft D_e' = 0,0574 ft $Re_a' = \frac{D_e' \times G_a}{\mu}$ $Re_a' = \frac{0,0574\ ft \times 11.860,9854\ lb/hr\ ft^2}{0,0411\ lb/ft\ hr}$ Re_a' = 16.564,9772 (Turbulen) *Fanning factor* untuk turbulen : $f = 0,0035 + \frac{0,264}{(DG/\mu)^{0,42}}$ Pers 3.47b DQ Kern	1. Re_p= 941,5825 (Laminar) *Fanning factor* untuk laminar : $f = \frac{16}{(DG/\mu)}$ Pers 3.46 DQ Kern $f = \frac{16}{(941,5825)}$ f = 0,0170 2. $\Delta F_p = \frac{4 \times f \times Gp^2 \times L}{2 \times g \times \rho^2 \times D_e}$ Pers 6.14 DQ Kern $g = 4,18 \times 10^8 ft/hr^2$ $\rho = 54,9287\ lb/ft^3$

$$f = 0{,}0035 + \frac{0{,}264}{(16.564{,}9772)^{0{,}42}}$$

$f = 0{,}0080$

2. $\Delta F_a = \frac{4 \times f \times Ga^2 \times L}{2 \times g \times \rho^2 \times D_e}$ Pers 6.14 DQ Kern

$g = 4{,}18 \times 10^8 \text{ ft/hr}^2$

$\rho = 57{,}1316 \text{ lb/ft}^3$

$$\Delta F_a = \frac{4 \times 0{,}0080 \times (11.860{,}9854 \text{ lb/hr ft})^2 \times 160 \text{ ft}}{2 \times 4{,}18 \times 10^8 \text{ft/hr} \times (57{,}1316 \text{ lb/ft}^3)^2 \times 0{,}0574 \text{ ft}}$$

$\Delta F_a = 0{,}0046$ ft

3. $V = \frac{G}{3600\rho}$

$$V = \frac{11.860{,}9854 \text{ lb/hr ft}^2}{3600 \times 57{,}1316 \text{ lb/ft}^3}$$

$V = 0{,}0577$ ft/s

$$\Delta F_l = \frac{V^2}{2g}$$

$$\Delta F_l = \frac{(0{,}0577 \text{ ft/s})^2}{2 \times 32{,}2 \text{ ft/s}^2}$$

$\Delta F_l = 0{,}00005$ ft

4. $\Delta P_a = \frac{(\Delta Fa + \Delta F1)\rho}{144}$ Pers 3.45 DQ Kern

$$\Delta P_a = \frac{(0{,}0046 \text{ ft} + 0{,}00005 \text{ ft})\ 57{,}1316 \text{ lb/ft}^3}{144}$$

$\Delta P_a = 0{,}0018$ psi

ΔP_a yang diizinkan=10 psi

0,0018 psi < 10 psi (Memenuhi)

$$\Delta F_p = \frac{4 \times 0{,}0170 \times (21.859{,}1419 \text{ lb/hr ft})^2 \times 160 \text{ ft}}{2 \times 4{,}18 \times 10^8 \text{ft/hr} \times (54{,}9287 \text{ lb/ft}^3)^2 \times 0{,}1723 \text{ ft}}$$

$\Delta F_p = 0{,}0120$ ft

3. $\Delta P_p = \frac{(\Delta Fp)\rho}{144}$ Pers 3.45 DQ Kern

$$\Delta P_a = \frac{(0{,}0120 \text{ ft})\ 54{,}9287 \text{ lb/ft}^3}{144}$$

$\Delta P_a = 0{,}0046$ psi

ΔP_a yang diizinkan=10 psi

0,0046 psi < 10 psi (Memenuhi)

3) *Deodorizer* (DE-1031)

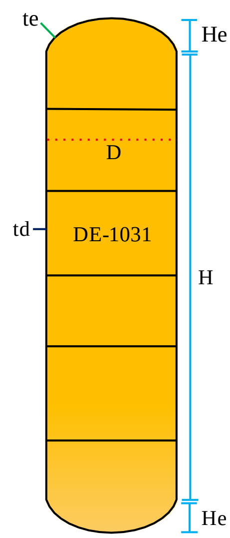
Fungsi : Tempat memisahkan komponen bau dari *palm fatty acid distillate*.

Tipe : *Sieve tray*

Bahan konstruksi : *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*

Jumlah : 1 unit

Fasa : Cair



Gambar LC-4. *Storage Tank PFAD*

1. Menentukan sifat-sifat fisika

- Densitas pada *top product*

Komponen	yD, D	ρ (kg/m3)	yD*ρ (kg/m3) liquid	ρ (kg/m3) gas	yD/ρ (kg/m3) Gas
H_2O	0,0173	849,15	14,69030	0,00374	6,E-05
$C_6H_{10}O$	0,2815	774,07	217,90071	0,02035	6,E-03
$C_7H_{14}O$	0,0724	641,39	46,43664	0,02367	2,E-03
$C_8H_{16}O$	0,0963	674,94	64,99672	0,02657	3,E-03
$C_9H_{18}O$	0,0002	685,89	0,13718	0,02948	6,E-06
$C_{29}H_{50}O_2$	0,0001	861	0,08610	0,08927	9,E-06
$C_{12}H_{24}O_2$	0,0102	759,4	7,74588	0,04152	4,E-04

$C_{14}H_{28}O_2$	0,0257	762,06	19,58494	0,04733	1,E-03
$C_{16}H_{32}O_2$	0,4201	761,27	319,80953	0,05315	2,E-02
$C_{18}H_{34}O_2$	0,0595	774,32	46,07204	0,05854	3,E-03
$C_{27}H_{46}O$	0,0004	1200,29	0,48012	0,08013	3,E-05
$C_{18}H_{32}O_2$	0,0024	776,94	1,86466	0,05813	1,E-04
$C_{18}H_{36}O_2$	0,0137	764,68	10,47612	0,05896	8,E-04
$C_{30}H_{50}$	0,0001	957,58	0,09576	0,08512	9,E-06
$C_{57}H_{104}O_6$	0,0000002	774,32	0,00015	0,18352	4,E-08
Total	**1,000**		**750,377**	**0,8595**	**0,0364**

- Densitas pada *bottom product*

Komponen	**xB, B**	**ρ (kg/m3)**	**xB/ρ (kg/m3)**	**ρ (kg/m3) gas**	**yB/ρ (kg/m3) Gas**
H_2O	0,000002	634,66	0,0013	0,00291	6,E-09
$C_6H_{10}O$	0,000100	548,34	0,0548	0,01586	2,E-06
$C_7H_{14}O$	0,000062	394,15	0,0244	0,01845	1,E-06
$C_8H_{16}O$	0,000282	465,06	0,1311	0,02072	6,E-06
$C_9H_{18}O$	0,000001	511,46	0,0005	0,02298	2,E-08
$C_{29}H_{50}O_2$	0,005236	761,45	3,9870	0,06959	4,E-04
$C_{12}H_{24}O_2$	0,001220	633,14	0,7724	0,03237	4,E-05
$C_{14}H_{28}O_2$	0,009035	648,65	5,8606	0,03690	3,E-04
$C_{16}H_{32}O_2$	0,385928	652,42	251,7871	0,04143	2,E-02
$C_{18}H_{34}O_2$	0,310606	666,48	207,0127	0,04564	1,E-02
$C_{27}H_{46}O$	0,008366	1082,11	9,0529	0,06247	5,E-04
$C_{18}H_{32}O_2$	0,086132	658,25	56,6964	0,04532	4,E-03
$C_{18}H_{36}O_2$	0,037878	661,28	25,0480	0,04596	2,E-03
$C_{30}H_{50}$	0,004189	808,73	3,3878	0,06636	3,E-04
$C_{57}H_{104}O_6$	0,150963	666,48	100,6138	0,14307	2,E-02
Total	**1,0000**		**664,4308**	**0,67003**	**0,0575**

2. Menghitung tegangan permukaan

$$\sigma = \left(\frac{P_{ch}(\rho_l - \rho_v)}{M}\right)^4 \times 10^{-12}$$ pers 8.23 coulson

- *Surface tension top product*

Komponen	BM (kg/kmol)	yD, D	pch	σ	yD x σ
H_2O	18	0,0173000	54,2	0,9545	0,01651285
$C_6H_{10}O$	98	0,2815000	243	0,7860	0,22125900
$C_7H_{14}O$	114	0,0724000	316,2	0,8792	0,06365408
$C_8H_{16}O$	128	0,0963000	355,2	0,8796	0,08470548
$C_9H_{18}O$	142	0,0002000	394,2	0,8800	0,00017600
$C_{29}H_{50}O_2$	430	0,0001000	1028,4	0,7581	0,00007581
$C_{12}H_{24}O_2$	200	0,0102000	545,4	0,8644	0,00881688
$C_{14}H_{28}O_2$	228	0,0257000	623,4	0,8667	0,02227419
$C_{16}H_{32}O_2$	256	0,4201000	701,4	0,8685	0,36485685
$C_{18}H_{34}O_2$	282	0,0595000	768,4	0,8637	0,05139015
$C_{27}H_{46}O$	386	0,0004000	936,2	0,7688	0,00030752
$C_{18}H_{32}O_2$	280	0,0024000	757,4	0,8574	0,00205776
$C_{18}H_{36}O_2$	284	0,0137000	779,4	0,8699	0,01191763
$C_{30}H_{50}$	410	0,0001000	999	0,7724	0,00007724
$C_{57}H_{104}O_6$	884	0,0000002	2335,5	0,8375	0,00000017
Total		**1,000**			**0,84808161**

σ mix top = 0,8481 dyne/cm

0,0008 N/m

- *Surface tension bottom product*

Komponen	BM (kg/kmol)	xB, B	pch	σ	xB x σ
H_2O	18	0,000002	54,2	0,5866	1,1732E-06
$C_6H_{10}O$	98	0,000100	243	0,4831	0,00004831
$C_7H_{14}O$	114	0,000062	316,2	0,5404	3,35048E-05
$C_8H_{16}O$	128	0,000282	355,2	0,5406	0,000152449
$C_9H_{18}O$	142	0,000001	394,2	0,5409	5,409E-07
$C_{29}H_{50}O_2$	430	0,005236	1028,4	0,4660	0,002439976
$C_{12}H_{24}O_2$	200	0,001220	545,4	0,5313	0,000648186
$C_{14}H_{28}O_2$	228	0,009035	623,4	0,5327	0,004812945
$C_{16}H_{32}O_2$	256	0,385928	701,4	0,5338	0,206008366
$C_{18}H_{34}O_2$	282	0,310606	768,4	0,5309	0,164900725
$C_{27}H_{46}O$	386	0,008366	936,2	0,4725	0,003952935
$C_{18}H_{32}O_2$	280	0,086132	757,4	0,5270	0,045391564
$C_{18}H_{36}O_2$	284	0,037878	779,4	0,5347	0,020253367
$C_{30}H_{50}$	410	0,004189	999	0,4747	0,001988518

$C_{57}H_{104}O_6$	884	0,150963	2335,5	0,5147	0,077700656
Total		**1,000000**			**0,528333216**

σ mix bottom = **0,5283** **dyne/cm**

0,0005 **N/m**

3. Menentukan diameter Menara

Dari neraca massa diketahui :

- Laju alir massa bagian atas

Feed (F) = 1.341,5322 kg/jam

Top product (D) = 102,1219 kg/jam

Vapor rate (V) = 188,4572 kg/jam

Liquid rate (L) = 86,3353 kg/jam

- Laju alir massa bagian bawah

Bottom product (B) = 1.279,6562 kg/jam

L' = 1.468,1135 kg/jam

V' = 188,4572 kg/jam

L' – V' = 1.279,6562 kg/jam

L' / V' = 7,7902 kg/jam

- *Liquid-vapor flow factor*

Tinggi *plate spacing* pada umumnya antara 0,3 – 0,6 m (Couldson Richardson Halaman 557), maka diambil *plate spacing* = 0,45 m.

$$F_{LV} = \frac{L_w}{V_w}\sqrt{\frac{\rho_v}{\rho_l}}$$ Pers 11.82 Couldson Richardson

ρ_l = Densitas cairan $\left(\frac{kg^3}{m}\right)$ V_w = Laju alir massa uap $\left(\frac{kg}{jam}\right)$

ρ_v = Densitas uap $\left(\frac{kg^3}{m}\right)$ L_w = Laju alir massa cairan $\left(\frac{kg}{jam}\right)$

Bagian atas

$$F_{LV} = \frac{86{,}3353 \text{ kg/jam}}{102{,}1219 \text{ kg/jam}} \sqrt{\frac{0{,}0364 \text{ kg/m}^3}{750{,}377 \text{ kg/m}^3}} = 0{,}0059$$

Dari data F_{LV} tersebut dimasukkan kedalam gambar 11.27 Couldson Richardson.

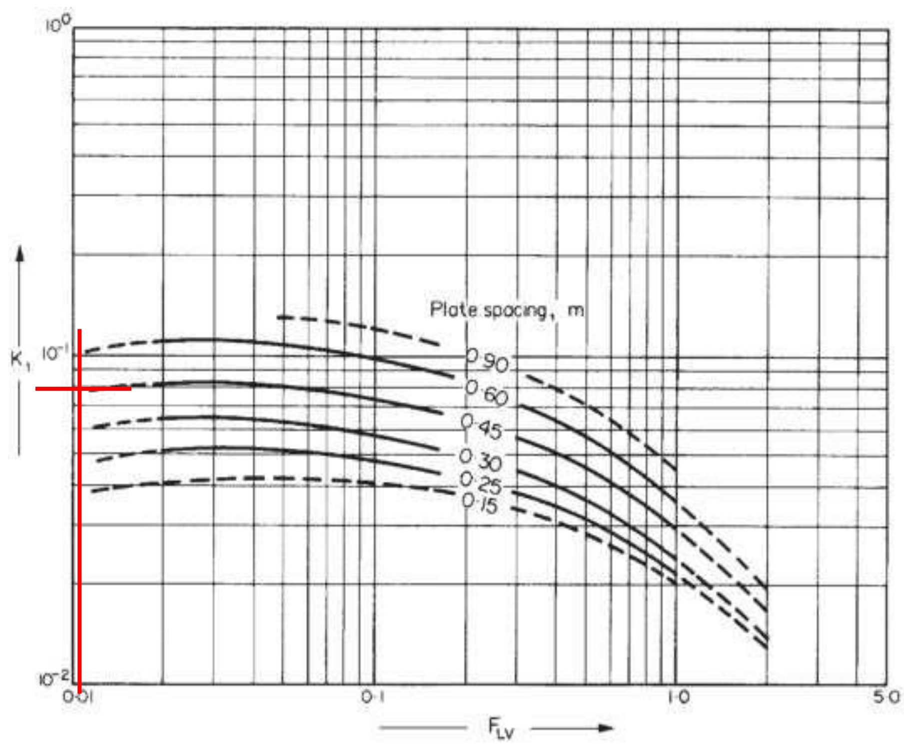


Figure 11.27. Flooding velocity, sieve plates

Dari gambar 11.27 diperoleh K1 *top* = 0,08

Koreksi nilai K1 *top*

$$K'_1 = K_1 \left(\frac{\sigma}{0{,}02}\right)^{0{,}2}$$ Couldson Richardson Halaman 569

$$K'_1 = 0{,}08 \left(\frac{0{,}0008 \text{ N/m}}{0{,}02}\right)^{0{,}2} = 0{,}0420$$

Bagian bawah

$$F_{LV} = \frac{1.468,1135 \text{ kg/jam}}{188,4572 \text{ kg/jam}} \sqrt{\frac{0,0575 \text{kg/m}^3}{664,4308 \text{ kg/m}^3}} = 0,0725$$

Dari data F_{LV} tersebut dimasukkan kedalam gambar 11.27 Couldson Richardson.

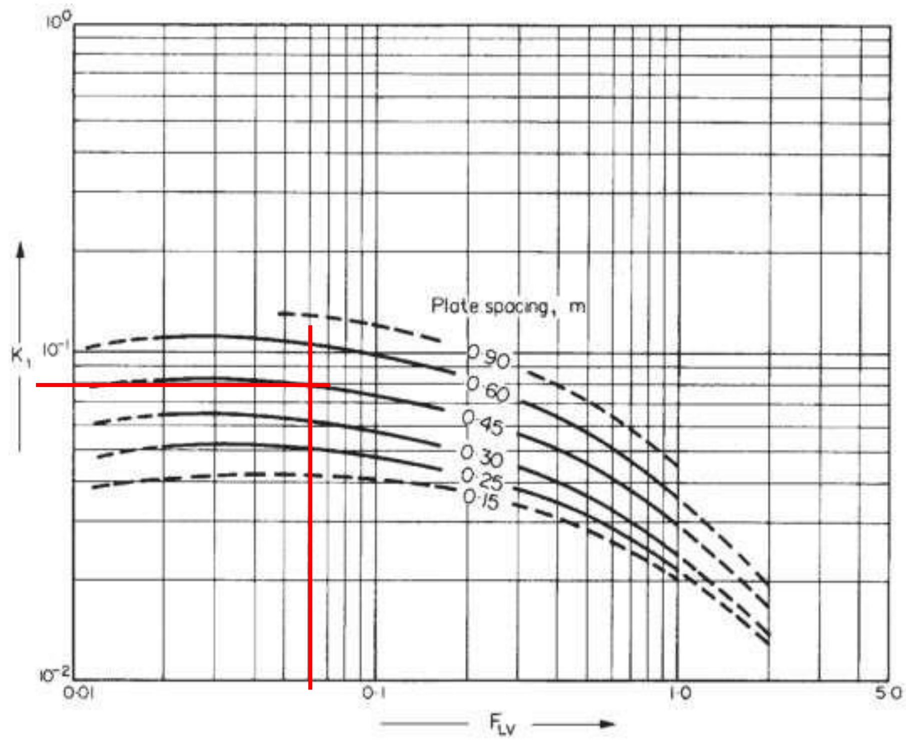


Figure 11.27. Flooding velocity, sieve plates

Dari gambar 11.27 diperoleh K1 *bottom* = 0,06

Koreksi nilai K1 *bottom*

$$K'_1 = K_1 \left(\frac{\sigma}{0,02}\right)^{0,2}$$ Couldson Richardson Halaman 569

$$K'_1 = 0,06 \left(\frac{0,0005 \text{ N/m}}{0,02}\right)^{0,2} = 0,0287$$

- Menentukan kecepatan *flooding*

$$u_f = K'_1 \sqrt{\frac{\rho_l - \rho_v}{\rho_v}}$$ Pers 11.81 Couldson Richardson

$$u_f\ ,Top = 0{,}0420\sqrt{\frac{750{,}3770\ kg/m^3 - 0{,}0364\ kg/m^3}{0{,}0364\ kg/m^3}} = 6{,}0301\ m/s$$

$$u_f\ ,Bottom = 0{,}0287\sqrt{\frac{664{,}4308\ kg/m^3 - 0{,}0575\ kg/m^3}{0{,}0575\ kg/m^3}} = 3{,}0850\ m/s$$

- Menentukan kecepatan uap

Kecepatan uap pada umumnya berkisar antara 70 – 90% dari kecepatan *flooding*, untuk perancangan biasanya diambil 80 – 85%, maka diambil 85% (Couldson Richardson Halaman 567 – 568)

u_v= 85% × u_f

u_v, *Top* = 85% × 6,0301 m/s = 5,1256 m/s

u_v, *Bottom* = 85% × 3,0850 m/s = 2,6223 m/s

- Menentukan laju alir volumetrik maksimum

$$Q_v = \frac{V_w}{\rho_v}$$

$$Q_v\ , Top = \left(\frac{188{,}4572\ kg/jam}{0{,}0364\ kg/m^3}\right) / 3600 = 1{,}4382\ m^3/s$$

$$Q_v\ , Bottom = \left(\frac{188{,}4572\ kg/jam}{0{,}0575\ kg/m^3}\right) / 3600 = 0{,}9104\ m^3/s$$

- Menentukan luas area netto untuk kontak uap-cair

$$A_n = \frac{Q_v}{u_v}$$ Couldson Richardson Halaman 581

$$A_n, \text{Top} = \frac{1{,}4382 \text{ m}^3/\text{s}}{5{,}1256 \text{ m/s}} = 0{,}2806 \text{ m}^2$$

$$A_n, \text{Bottom} = \frac{0{,}9104 \text{ m}^3/\text{s}}{2{,}6223 \text{ m/s}} = 0{,}3472 \text{ m}^2$$

- Menentukan luas penampang lintang menara

$$A_c = \frac{A_n}{1 - A_d}$$ Couldson Richardson Halaman 581

A_d = Luas penampang *downcomer*

Luas penampang *downcomer* adalah 12% dari luas keseluruhan.

$$A_c, \textit{Top} = \frac{0{,}2806 \text{ m}^2}{1 - 0{,}12} = 0{,}3189 \text{ m}^2$$

$$A_c, \textit{Bottom} = \frac{0{,}3472 \text{ m}^2}{1 - 0{,}12} = 0{,}3945 \text{ m}^2$$

- Menentukan diameter menara berdasarkan kecepatan *flooding*

$$D_c = \sqrt{\frac{4A_c}{\pi}}$$ Pers 11.80 Couldson Richardson

$$D_c, \textit{Top} = \sqrt{\frac{4 \times 0{,}3189 \text{ m}^2}{3{,}14}} = 0{,}6374 \text{ m}$$

$$D_c, \textit{Bottom} = \sqrt{\frac{4 \times 0{,}3945 \text{ m}^2}{3{,}14}} = 0{,}7089 \text{ m}$$

- Menentukan jenis aliran

$$Q_{L,\,B} = \frac{L_{w,\,B}}{\rho_{l,\,B}}$$ Couldson Richardson Halaman 581

$$Q_{L,\,B} = \frac{1.468{,}1135 \text{ kg/jam}}{664{,}4308 \text{ kg/m}^3} \times 3600 = 0{,}0006 \text{ m}^3/\text{s}$$

Dari gambar 11.28 Couldson & Richardson, untuk $Q_{L,B}$ = 0,0006 m^3/s maka jenis alirannya adalah *cross flow* (*single pass*).

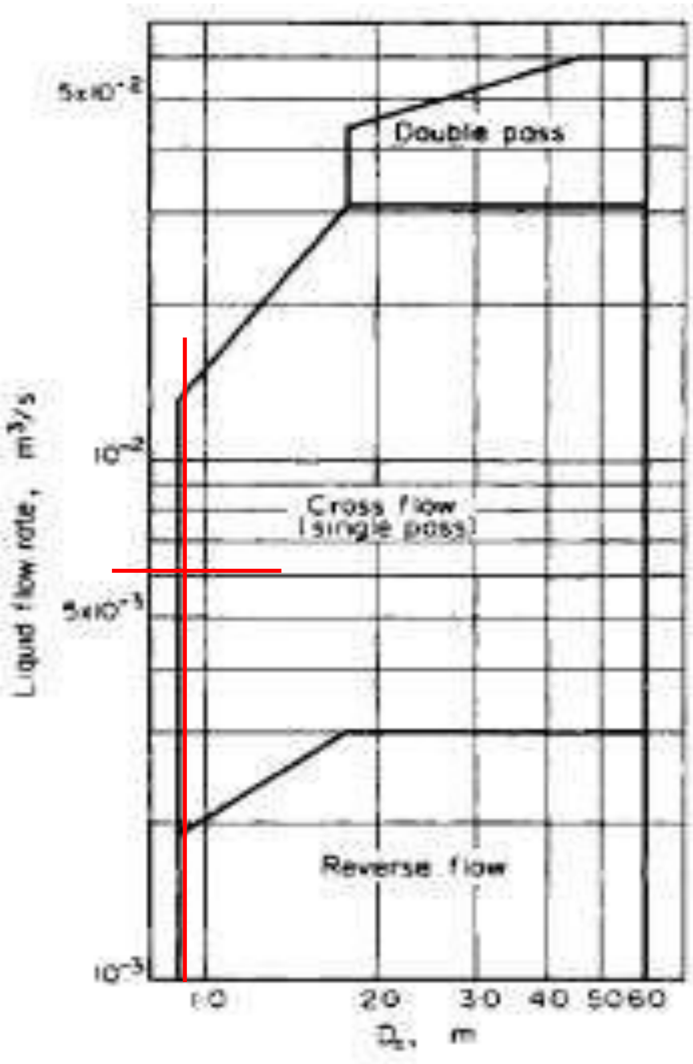


Figure 11.28. Selection of liquid-flow arrangement

4. Perancangan *Tray*

Data yang dibutuhkan :

Diameter Menara, D_c	= 0,7089 m
Luas Menara, A_c, $(\frac{3,14}{4} \times D_c^2)$	= 0,3935 m^2
Luas *Downcomer*, A_d, 0,12 A_c	= 0,0473 m^2

Luas *netto*, A_n, $A_c - A_d$ = 0,3472 m^2

Luas aktif, A_a, $A_c - 2A_d$ = 0,2999 m^2

Luas *hole*, A_h, 10% A_a = 0,0300 m^2

A_d/A_c = 0,1199

Berdasarkan Couldson Richardson halaman 568, diperoleh nilai hubungan antara *downcomer area* dan panjang *weir*, l_w/D_c =0,77

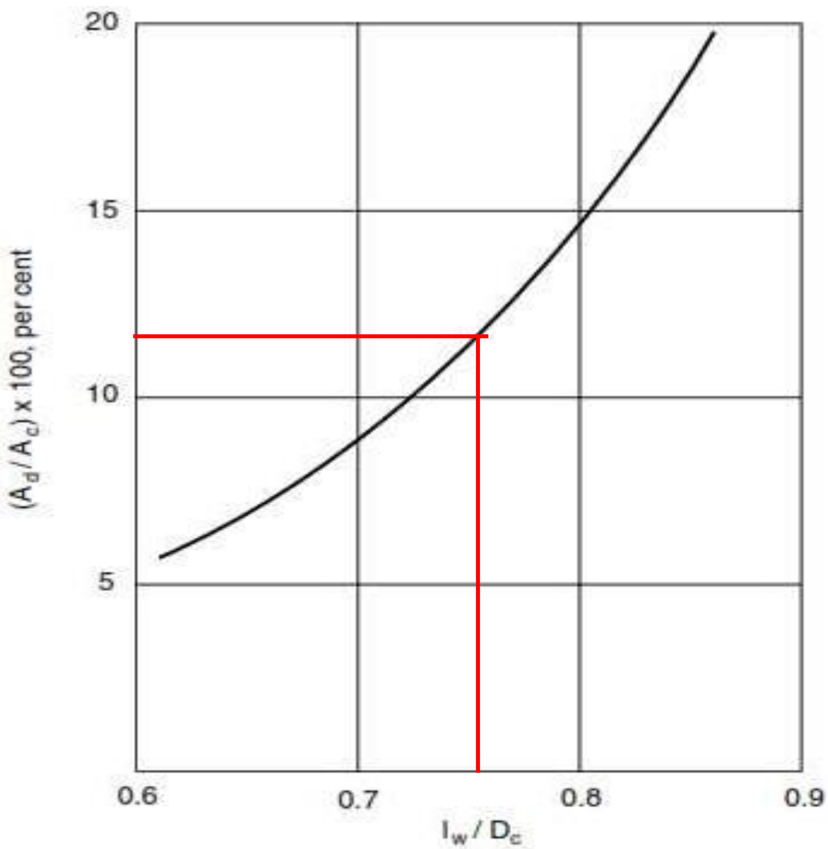


Figure 11.31. Relation between downcomer area and weir length

Panjang *weir*, l_w = 077 × 0,7089 m = 0,5459 m

Tinggi *weir*, h_w = 20 mm = 0,02 m (Couldson Richardson Halaman 572)

Diameter *hole*, D_h = 5 mm = 0,005 m (Couldson Richardson Halaman 572)

Tebal *tray* = 3 mm = 0,003 m (Couldson Richardson Halaman 572)

- Pemeriksaan *weeping rate*

L_w max = 0,4078 kg/s

Turn down ratio = 70%

L_w min = 0,2855 kg/s

Tinggi *weir liquid crest*

Bagian atas

$$h_{ow} = 750 \left(\frac{L_w}{\rho_l \times l_w}\right)^{2/3}$$

$$h_{ow}\ \text{Max} = 750 \left(\frac{0{,}4078\ \text{kg/s}}{750{,}3770\ \text{kg/m}^3 \times 0{,}5459\ \text{m}}\right)^{2/3} = 7{,}4759\ \text{mm liquid}$$

$$h_{ow}\ \text{Min} = 750 \left(\frac{0{,}2855\ \text{kg/s}}{750{,}3770\ \text{kg/m}^3 \times 0{,}5459\ \text{m}}\right)^{2/3} = 5{,}8943\ \text{mm liquid}$$

Pada minimum *rate* ($h_{ow} + h_w$) = 25,8943 mm liquid

Kemudian berdasarkan gambar 11.30 Couldson Richardson diperoleh konstanta (K_2) = 28,9.

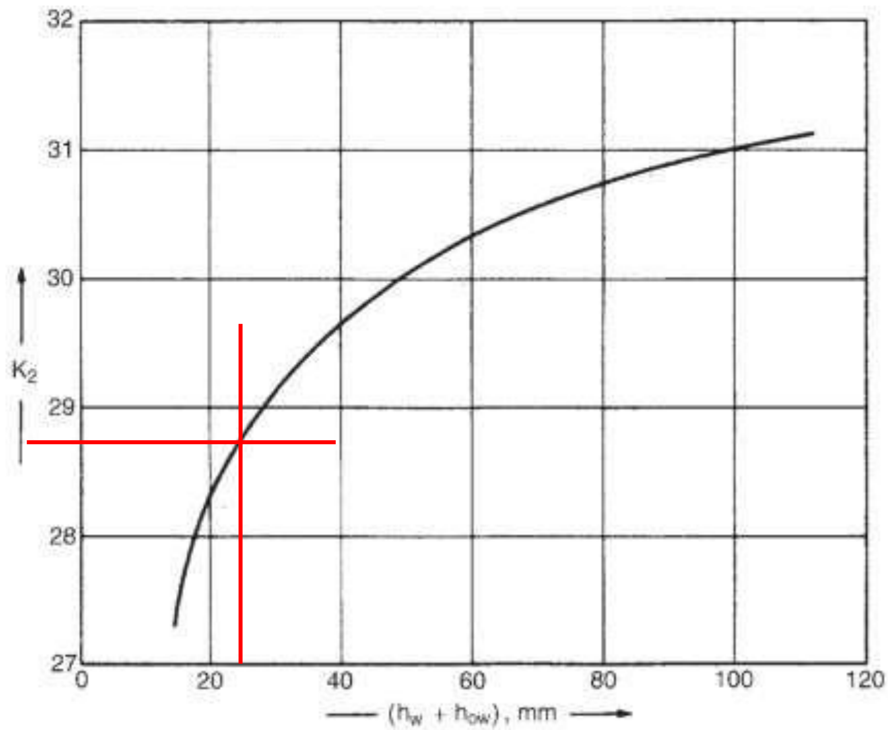


Figure 11.30. Weep-point correlation (Eduljee, 1959)

Maka kecepatan uap minimum desain dapat dicari dengan persamaan berikut.

$$U_h = \frac{(K_2 - 0{,}90(25{,}4 - D_h))}{(\rho_v)^{1/2}}$$ Pers 11.84 Couldson Richardson

$$U_h = \frac{(28{,}9 - 0{,}90(25{,}4 - 5\ mm))}{(0{,}0364\ kg/m^3)^{1/2}} = 55{,}2446\ m/s$$

Kecepatan uap minimum aktual

$$U_{am} = \frac{Q_{v,f}}{A_h}$$ Couldson Richardson Halaman 582

$$U_{am} = \frac{1{,}4382\ m^3/s}{0{,}03\ m^2} = 47{,}9400\ m/s$$

$U_{am} < U_h$ maka tidak terjadi *weeping*

Bagian bawah

$$h_{ow} = 750 \left(\frac{L_w}{\rho_l \times l_w}\right)^{2/3}$$

$$h_{ow}\ Max = 750 \left(\frac{0,4078\ kg/s}{664,4308\ kg/m^3 \times 0,5459\ m}\right)^{2/3} = 8,1075\ mm\ liquid$$

$$h_{ow}\ Min = 750 \left(\frac{0,2855\ kg/s}{664,4308\ kg/m^3 \times 0,5459\ m}\right)^{2/3} = 6,3922\ mm\ liquid$$

Pada minimum *rate* ($h_{ow} + h_w$) = 26,3922 mm liquid

Kemudian berdasarkan gambar 11.30 Couldson Richardson diperoleh konstanta (K_2) = 28,9.

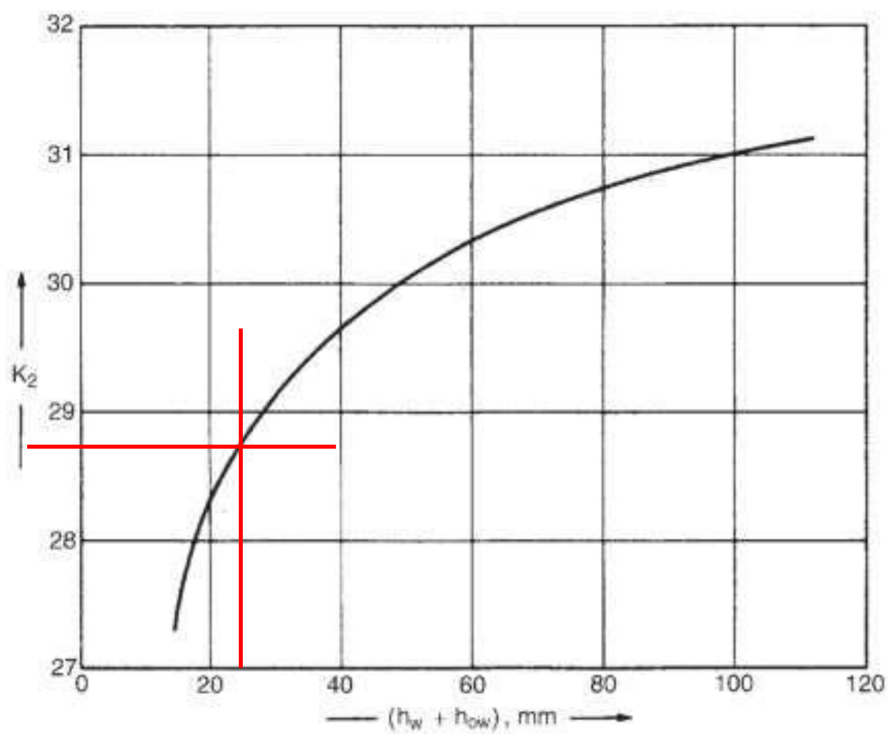


Figure 11.30. Weep-point correlation (Eduljee, 1959)

Maka kecepatan uap minimum desain dapat dicari dengan persamaan berikut.

$$U_h = \frac{(K_2 - 0{,}90(25{,}4 - D_h))}{(\rho_v)^{1/2}}$$ Pers 11.84 Couldson Richardson

$$U_h = \frac{(28{,}9 - 0{,}90(25{,}4 - 5\ mm))}{(0{,}0575\ kg/m^3)^{1/2}} = 43{,}9548\ m/s$$

Kecepatan uap minimum aktual

$$U_{am} = \frac{Q_{v,f}}{A_h}$$ Couldson Richardson Halaman 582

$$U_{am} = \frac{0{,}9104\ m^3/s}{0{,}03\ m^2} = 30{,}3467\ m/s$$

$U_{am} < U_h$ maka tidak terjadi *weeping*

- *Plate pressure drop*

Bagian atas

Dry plate drop

Dari gambar 11.34 Couldson Richardson, untuk ketebalan plate/diameter *hole* = 0,6 dan nilai A_h/A_a *100 = 10, maka diperoleh nilai dari *orifice coefficient,* C_o = 0,74.

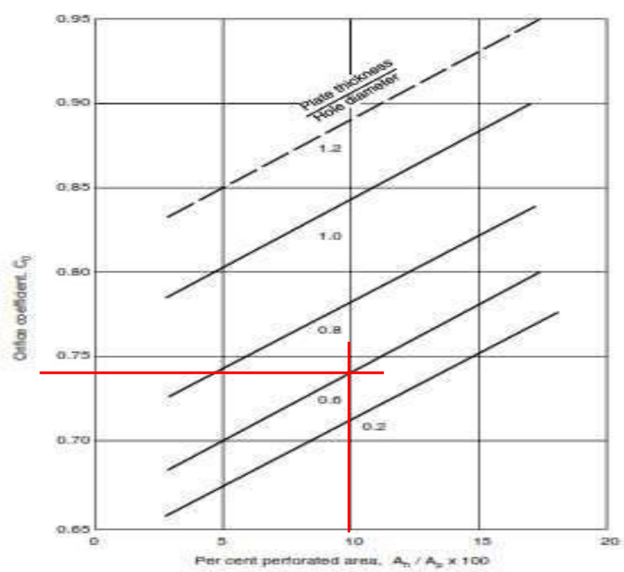


Figure 11.34. Discharge coefficient, sieve plates (Liebson *et al.*, 1957)

$$h_d = 51 \left(\frac{U_{am}}{C_o}\right)^2 \left(\frac{\rho_v}{\rho_l}\right)$$ Pers 11.88 Couldson Richardson

$$h_d = 51 \left(\frac{55,2446 \text{ m/s}}{0,74}\right)^2 \left(\frac{0,0364 \text{ kg/m}^3}{750,3770 \text{ kg/m}^3}\right) = 10,3830 \text{ mm liquid}$$

Residual head

$$h_r = \frac{12,5 \times 10^3}{\rho_l}$$ Pers 11.89 Couldson Richardson

$$h_r = \frac{12,5 \times 10^3}{750,3770 \text{ kg/m}^3} = 16,6583 \text{ mm liquid}$$

Total drop

$h_t = h_d + (h_w + h_{ow}) + h_r$ Pers 11.89 Couldson Richardson

$h_t = (10,3830 + (25,8943) + 16,6583)$ mm liquid = 52,9356 mm liquid

Total plate pressure drop

$\Delta P_t = 9,81 \times 10^{-3} \times h_t \times \rho_l$ Pers 11.87 Couldson Richardson

$\Delta P_t = 9,81 \times 10^{-3} \times 52,9356 \times 750,3770 \text{ kg/m}^3 = 351,9456$ Pa

Bagian Bawah

Dry plate drop

Dari gambar 11.34 Couldson Richardson, untuk ketebalan plate/diameter *hole* = 0,6 dan nilai A_h/A_a *100 = 10, maka diperoleh nilai dari *orifice coefficient,* C_o = 0,74.

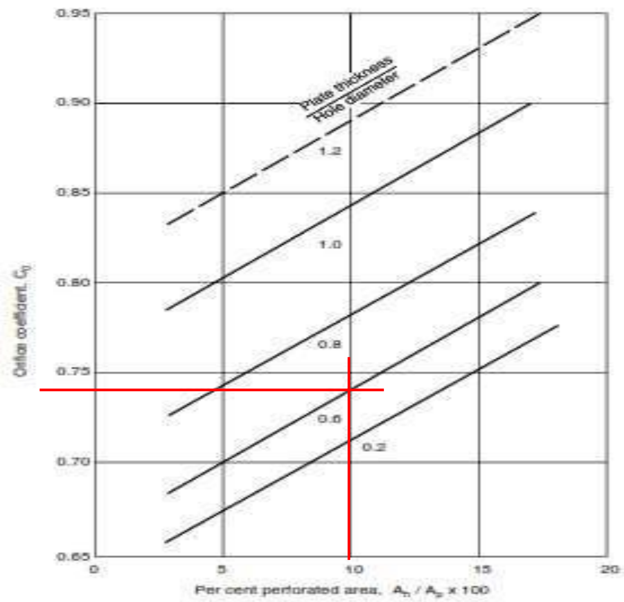


Figure 11.34. Discharge coefficient, sieve plates (Liebson *et al.*, 1957)

$h_d = 51 \left(\frac{U_{am}}{C_o}\right)^2 \left(\frac{\rho_v}{\rho_l}\right)$ Pers 11.88 Couldson Richardson

$h_d = 51 \left(\frac{30{,}3467 \text{ m/s}}{0{,}74}\right)^2 \left(\frac{0{,}0575 \text{ kg/m}^3}{664{,}4308 \text{ kg/m}^3}\right) = 7{,}4225$ mm liquid

Residual head

$h_r = \frac{12{,}5 \times 10^3}{\rho_l}$ Pers 11.89 Couldson Richardson

$h_r = \frac{12{,}5 \times 10^3}{664{,}4308 \text{ kg/m}^3} = 18{,}8131$ mm liquid

Total drop

$h_t = h_d + (h_w + h_{ow}) + h_r$ Pers 11.89 Couldson Richardson

$h_t = (7{,}4225 + (26{,}3922) + 18{,}8131)$ mm liquid = 52,6278 mm liquid

Total plate pressure drop

$\Delta P_t = 9{,}81 \times 10^{-3} \times h_t \times \rho_l$ Pers 11.87 Couldson Richardson

$\Delta P_t = 9{,}81 \times 10^{-3} \times 52{,}6278 \times 664{,}4308 \text{ kg/m}^3 = 343{,}0315 \text{ Pa}$

- *Downcomer liquid back up*

Bagian atas

$h_{ap} = h_w$ - (5 sampai 10 mm)   Couldson Richardson Halaman 583

Dipilih 6 mm

h_{ap} = 20 mm - 6 mm = 14 mm

$A_{ap} = h_{ap} \times l_w$ Couldson Richardson Halaman 583

A_{ap} = 14 mm × 0,5459 m × 10^{-3} = 0,0076 m^2

$$h_{dc} = 166 \left(\frac{L_w}{\rho_l \times A_{ap}}\right)^2$$ Couldson Richardson Halaman 583

$$h_{dc} = 166 \left(\frac{0{,}4078 \text{ kg/s}}{750{,}3770 \text{ kg/m}^3 \times 0{,}0076 \text{ m}^2}\right)^2 = 0{,}8488 \text{ mm}$$

Back up in downcomer

$h_b = (h_{ow} + h_w) + h_t + h_{dc}$ Couldson Richardson Halaman 583

h_b = (25,8943) + 52,9356 + 0,8488 = 79,3709 mm = 0,0794 m

$h_b < \frac{1}{2}$(*plate spacing* + *weir height*)

0,07 m < $\frac{1}{2}$(0,45 m + 0,02 m)

0,07 m < 0,235 (pemilihan *plate spacing* tepat)

Bagian bawah

$h_{ap} = h_w$ - (5 sampai 10 mm)   Couldson Richardson Halaman 583

Dipilih 6 mm

h_{ap} = 20 mm - 6 mm = 14 mm

$A_{ap} = h_{ap} \times l_w$ Couldson Richardson Halaman 583

A_{ap} = 14 mm × 0,5459 m × 10^{-3} = 0,0076 m^2

$$h_{dc} = 166 \left(\frac{L_w}{\rho_l \times A_{ap}}\right)^2$$ Couldson Richardson Halaman 583

$$h_{dc} = 166 \left(\frac{0,4078 \text{ kg/s}}{664,4308 \text{ kg/m}^3 \times 0,0076 \text{ m}^2}\right)^2 = 1,0826 \text{ mm}$$

Back up in downcomer

$h_b = (h_{ow} + h_w) + h_t + h_{dc}$ Couldson Richardson Halaman 583

h_b = (26,3922) + 52,6278 + 1,0826 = 80,1026 mm = 0,0801 m

$h_b < \frac{1}{2}$(*plate spacing* + *weir height*)

0,08 m < $\frac{1}{2}$(0,45 m + 0,02 m)

0,08 m < 0,235 (pemilihan *plate spacing* tepat)

- *Check residence time*

$$t_r = \frac{A_d \times h_b \times \rho_l}{L_w}$$ Pers 11.95 Couldson Richardson

Jika t_r > 3 s, maka tidak terjadi gelembung udara pada cairan yang masuk melalui *downcomer.*

$$t_r, Top = \frac{0,0473 \text{ m}^2 \times 0,0794 \text{ m} \times 750,3770 \text{ kg/m}^3}{0,4078 \text{ kg/s}} = 6,9106 \text{ s}$$

6,9106 s > 3 maka tidak terjadi gelembung udara.

$$t_r, \textit{Bottom} = \frac{0{,}0473\ m^2 \times 0{,}0801\ m \times 664{,}4308\ kg/m^3}{0{,}4078\ kg/s} = 6{,}1730\ s$$

6,1730 s > 3 maka tidak terjadi gelembung udara.

- *Check entraiment*

Actual percentage flooding for design area

Bagian atas

$$\%\ flooding = \frac{U_{am}}{U_h} \times 100\% \quad \text{Pers 11.83 Couldson Richardson}$$

$$\%\ flooding = \frac{47{,}9400\ m/s}{55{,}2446\ m/s} \times 100\% = 86{,}78\%$$

$F_{LV} = 0{,}0059$

Dari kedua data tersebut kemudian dimasukkan kedalam gambar 11.29 Couldson Richardson dan diperoleh nilai dari *fractional entraiment.* Jika nilai nya < 0,1 maka tidak terjadi *entrainment.*

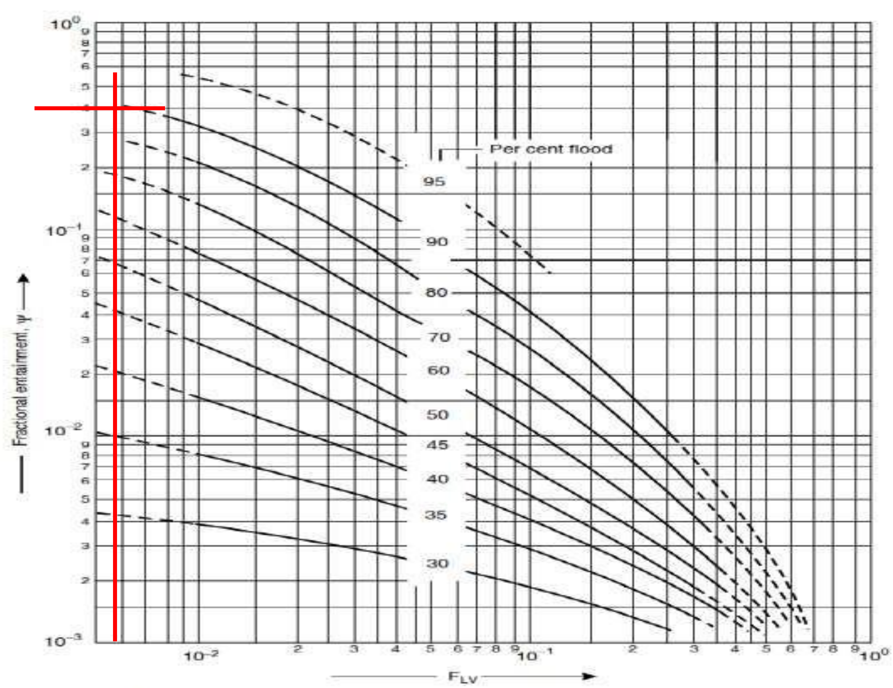


Figure 11.29. Entrainment correlation for sieve plates (Fair, 1961)

Diperoleh nilai Ψ = 0,4 ; 0,4 > 0,1 maka terjadi *entrainment.*

Bagian bawah

$$\% \text{ flooding} = \frac{U_{am}}{U_h} \times 100\% \quad \text{Pers 11.83 Couldson Richardson}$$

$$\% \text{ flooding} = \frac{30{,}3467 \text{ m/s}}{43{,}9548 \text{ m/s}} \times 100\% = 69{,}04\%$$

$F_{LV} = 0{,}0725$

Dari kedua data tersebut kemudian dimasukkan kedalam gambar 11.29 Couldson Richardson dan diperoleh nilai dari *fractional entraiment.* Jika nilai nya < 0,1 maka tidak terjadi *entrainment.*

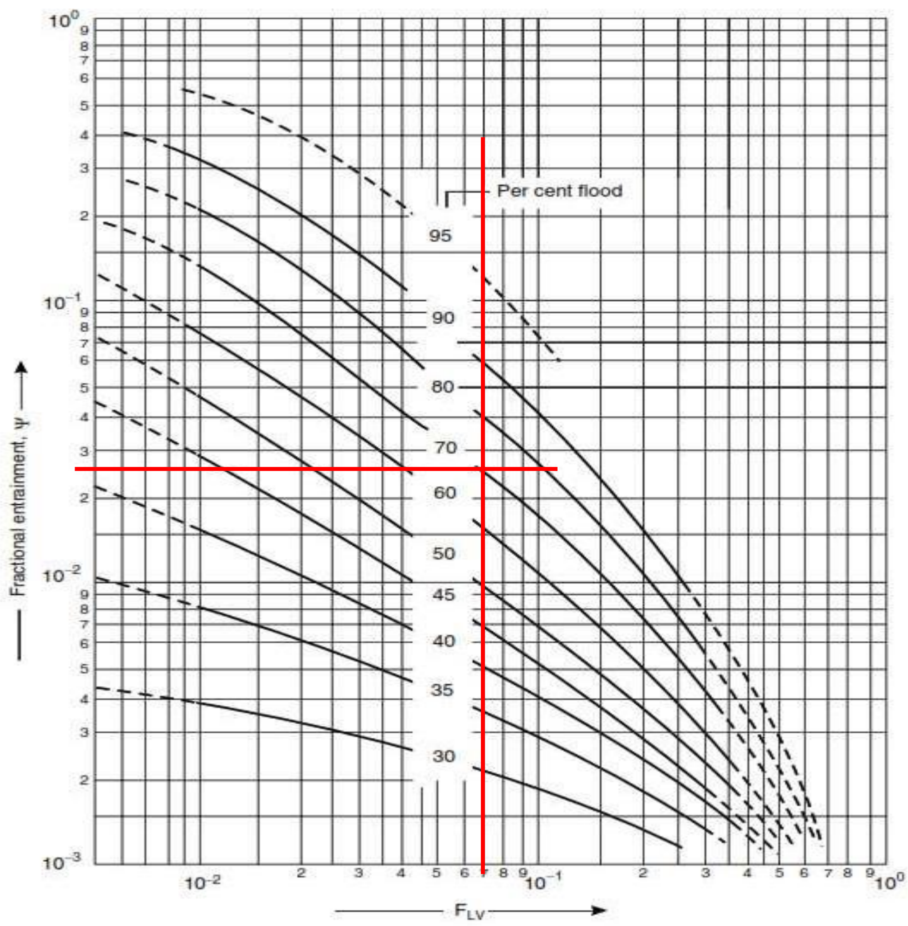
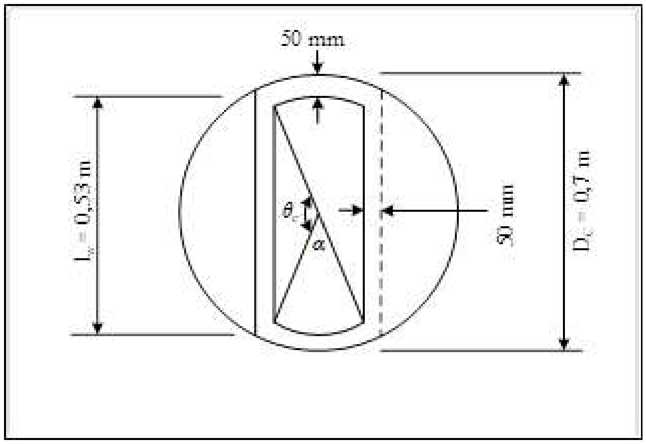


Figure 11.29. Entrainment correlation for sieve plates (Fair, 1961)

Diperoleh nilai Ψ = 0,027 ; 0,027 > 0,1 maka tidak terjadi *entrainment.*

- *Trial layout tray*



l_w/D_c = 0,77

Data l_w/D_c kemudian di masukkan kedalam gambar 11.32 Couldson Richardson Halaman 574.

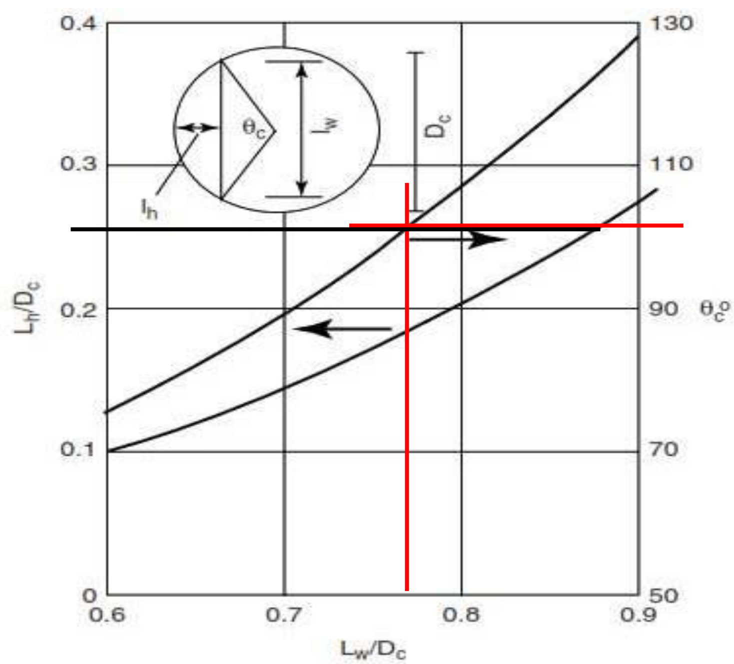


Figure 11.32. Relation between angle subtended by chord, chord height and chord length

Dari gambar 11.32 diperoleh data berikut.

$\theta_c = 99°$

Derajat *tray edge*

$\alpha = 81°$ $\qquad \frac{L_h}{D_c} = 0,24$

Panjang rata-rata *unperforated edge strips*

$L_{av} = \frac{\alpha}{180} \times \pi \times (D_c - 0,05)$ Couldson Richardson Halaman 584

$L_{av} = \frac{81°}{180} \times 3,14 \times (0,7089\ m - 0,05) = 0,9310\ m$

Luas *unperforated edge strips*

Berdasarkan Couldson Richardson Richardson halaman 583 *unferporated strip round plate edge* = 50 mm atau 0,05 m.

$A_{up} = 0,05\ m \times L_{av}$ Couldson Richardson Halaman 584

$A_{up} = 0,05\ m \times 0,9310\ m = 0,0466\ m^2$

Panjang rata-rata *calming zone*

$L_{cz} = l_w +$ *width of unperforated strip* Couldson Richardson Halaman 584

Berdasarkan Couldson Richardson halaman 583 *width of unperforated strip* = 50 mm atau 0,05 m.

$L_{cz} = 0,5459\ m + 0,05\ m = 0,0273\ m$

Area of calming zone

$A_{cz} = 2(L_{cz} \times \text{width of unperforated strip})$ Couldson Richardson Halaman 584

$A_{cz} = 2(0,0273\ m \times 0,05\ m) = 0,0027\ m^2$

Total area for perforations

$A_p = A_a - A_{up} - A_{cz}$ Couldson Richardson Halaman 584

$A_p = 0{,}2999\ m^2 - 0{,}0466\ m^2 - 0{,}0027\ m^2 = 0{,}2506\ m^2$

$A_h = 0{,}003\ m^2$

$A_h/A_p = 0{,}12$

Kemudian data tersebut dimasukkan kedalam gambar 11.33 Couldson Richardson dan diperoleh nilai $l_p/d_h = 2{,}8$

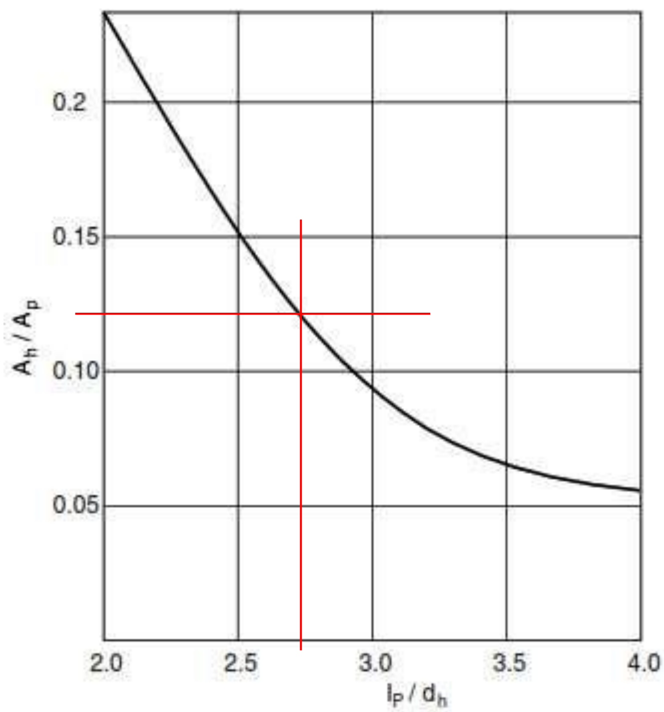


Figure 11.33. Relation between hole area and pitch

Hole pitch

$$I_p = \frac{I_p}{d_h} \times d_h$$ Couldson Richardson Halaman 584

I_p = 2,8 × 5 mm = 14 mm

Luas lubang

Luas 1 lubang = $\frac{\pi}{4} \times d_h^{\,2}$ Couldson Richardson Halaman 584

Luas 1 lubang = $\frac{3,14}{4} \times (5\text{ mm})^2 = 19,625\text{ mm}^2 = 1,9625 \times 10^{-5}\text{ m}^2$

Jumlah lubang

Jumlah lubang = $\frac{A_h}{\text{Luas 1 lubang}}$ Couldson Richardson Halaman 584

Jumlah lubang = $\frac{0,03\text{ m}^2}{1,9625 \times 10^{-5}\text{ m}^2}$ = 1529 buah

5. Spesifikasi *Tray*

Diameter *tray,* D_c = 0,7089 m

Diameter lubang, D_h = 0,005 m

Hole pitch, I_p = 0,014 m

Jumlah *hole* = 1529 buah

Turn down ratio = 70%

Material *tray* = *Stainless stell* (SA-240 *grade 304*)

Material *downcomer* = *Stainless stell* (SA-240 *grade 304*)

Tray spacing = 0,45 m

Tray thickness = 0,003 m

Panjang *weir* = 0,5459 m

Tinggi *weir* = 0,02 m

Plate pressure drop = 52,9356 mm liquid

- Menentukan tebal dinding dan *head* Menara

Desain Menara = silinder vertikal dengan alas dan tutup *ellipsoidal*

Bahan konstruksi = *Stainless stell* (SA-240 *grade 304*)

P_d = 0,1176 psi

R = 13,9547 in

S = 18700 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

Tebal dinding Menara

$$t_d = \frac{PR}{SE - 0{,}6P} + C$$ *Walas - Chemical Process Equipment, Table 18.4, Page 658*

$$t_d = \frac{0{,}1176 \text{ psi} \times 13{,}9547 \text{ in}}{18700 \text{ psi} \times 0{,}85 - 0{,}6 \times 0{,}1176 \text{ psi}} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun} = 0{,}2001 \text{ in}$$

= 0,0051 m

= 0,0167 ft

= 5,0825 mm

Outside diameter

OD = ID + $2t_d$

OD = 0,7089 m + 2(0,0051 m) = 0,7191 m

Tinggi *ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 0,7089$ m

$H_e = 0,1772$ m

Tebal *ellipsoidal*

$$t_e = \frac{PD}{2SE - 0,2P} + C$$ *Walas - Chemical Process Equipment, Table 18.4*

$$t_e = \frac{0,1176\ \text{psi} \times 27,9094\ \text{in}}{2 \times 18700\ \text{psi} \times 0,85 - 0,2 \times 0,1176\ \text{psi}} + 0,02\ \text{in/tahun} \times 10\ \text{tahun} = 0,2001\ \text{in}$$

= 0,0051 m

= 0,0167 ft

= 5,0825 mm

Tinggi Menara

H = (N_{act} × *plate spacing*) + (N_{act} × tebal *plate*)

N_{actual} = 14

Plate spacing = 0,45 m

Tebal *plate* = 3 mm = 0,003 m

H = (14 × 0,45 m) + (14 × 0,003 m) = 6,342 m

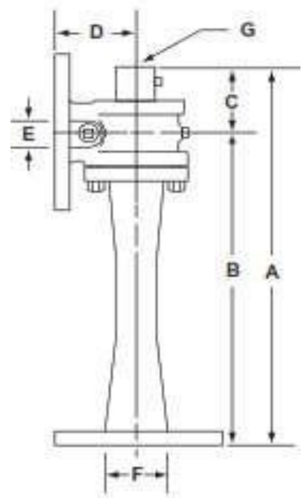
4) *Steam Jet Ejector* (JE-1041)

Fungsi : Memvakumkan *deodorizer*

Tipe : *Single stage steam ejector*

Bahan konstruksi : *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*

Jumlah : 1 unit



Gambar LC-5. *Steam Jet Ejector*

1. Total uap yang ditangani

$W_m = 102,1219 \dfrac{kg}{jam} = 225,138 \dfrac{lb}{jam}$

2. Tekanan yang harus divakumkan

P_{vakum}= 6 mmHg = 0,2368 Hg

3. Kebutuhan *steam*

- ***Pounds of motive steam per lb of mixture handled***

Untuk mencari *pounds of motive steam per lb of mixture handled* dapat dilakukan dengan menggunakan gambar 6-28B *Ludwig – Applied Process Design 3^rd^ ed.*

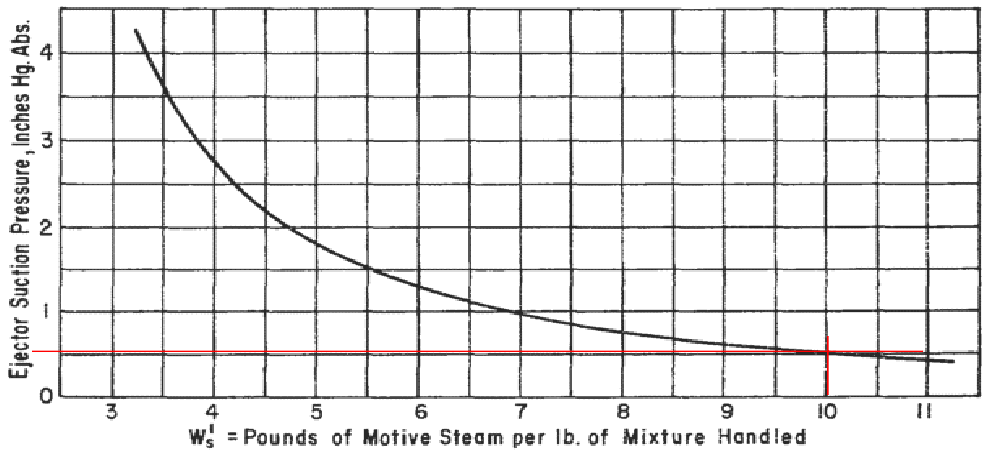


Figure 6-28B. Steam consumption factor. By permission, Worthington Corp.

Diperoleh nilai W'_{s} = 10 lb.

Asumsi W_a (*non-condensable gas*) 10% dari umpan

W_a = 22,5138 lb/jam

$\frac{W_a}{W_m}$ = 0,1 lb/jam

Kemudian nilai dari W_a/W_m dimasukkan kedalam gambar 6-28C *Ludwig – Applied Process Design 3^rd ed* untuk mencari nilai K (*non-condensable load factor*)

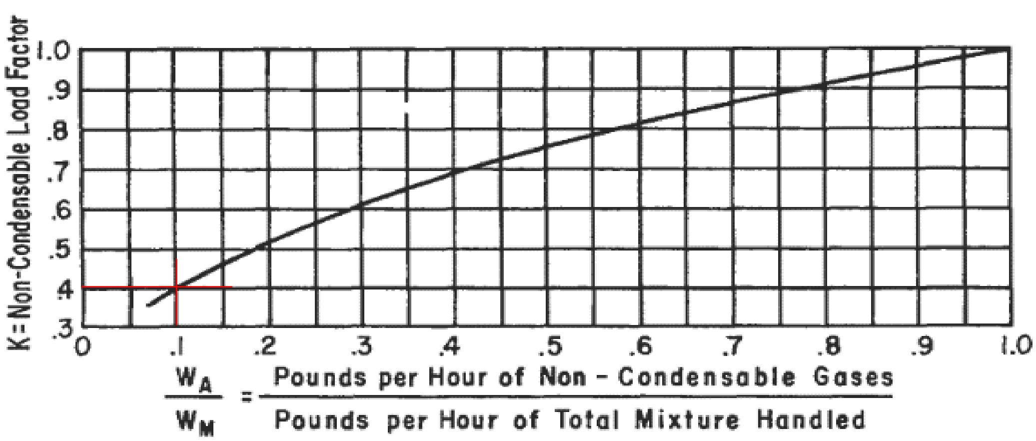


Figure 6-28C. Non-condensable load factor. By permission, Worthington Corp.

Dari gambar 6-28C diperoleh nilai K = 0,4

Tekanan *steam* yang digunakan = 1.311,1 kPa = 190,1523 Psig

Temperatur *steam* yang digunakan = 242 ^oC

Kemudian nilai dari Tekanan *steam* dimasukkan kedalam gambar 6-28C *Ludwig – Applied Process Design 3rd ed* untuk mencari nilai F (*steam pressure factor)*

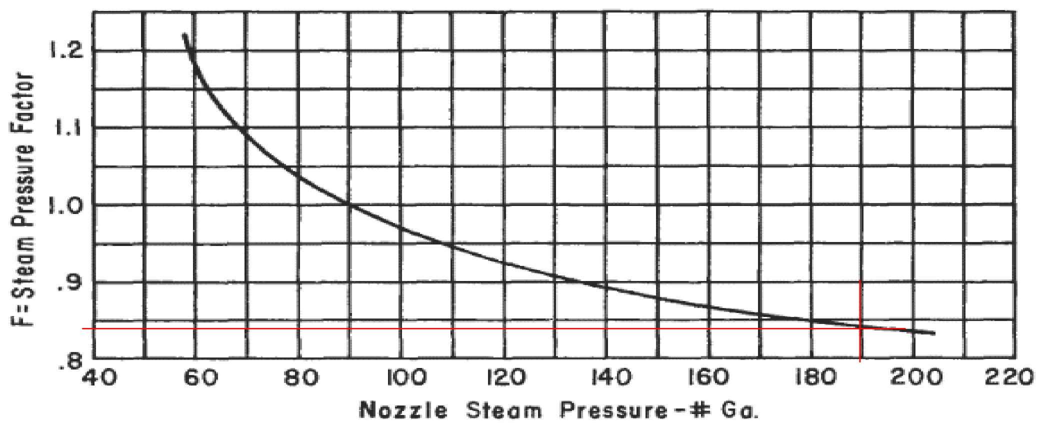


Figure 6-28D. Steam pressure factor. By permission, Worthington Corp.

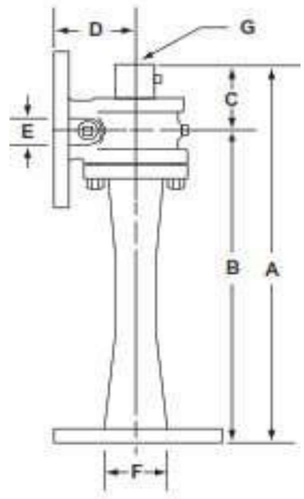
Dari gambar 6-28D diperoleh nilai F = 0,84

Maka kebutuhan *steam* sebenarnya adalah sebagai berikut.

W_s= W'_s ×W_m× K × F Persamaan 6.22 *Ludwig – Applied Process Design 3rd ed*

W_s= 10 × 225,138 lb/jam × 0,4 × 0,84 = 756,4638 lb/jam = 1.666,22 kg/jam

Kemudian Adapun dimensi dari *steam jet ejector* diambil dari s*tandard construction* (*Schutte & Koerting*) seperti pada table berikut.



Noozle size (in)	Unit Dimensions (in)				Connections (in)			Net Weight (lbs)
	A	B	C	D	E	F	G	
3	31	26	5	4	3	3	2	83

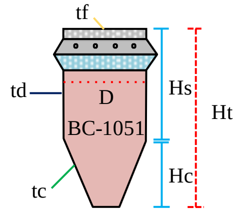
5) ***Barometric Condensor* (BC-1051)**

Fungsi : Mengkondensasikan uap yang keluar dari *steam jet ejector*

Tipe : *Counter-current dry air condensor*

Bahan konstruksi : *Carbon steel 70 C-Si (SA-515 Grade 70)*

Jumlah : 1 unit



Gambar LC-6. *Barometric Condensor*

Laju alir massa (Q) = 1.666,2198 kg/jam = 3.673,3482 lb/jam

Densitas = 1000 kg/m^3

Volumetrik (V) = 1,6662 m^3/jam

Kecepatan aliran = 2 m/s = 6,5620 ft/s *(Hugot – Handbook Of Cane Sugar Engineering 3rd ed Page 882)*

Luas Penampang kondensor

$$S = 1{,}7 \frac{ft^2}{ton} \times \text{uap yang akan di kondensasikan}$$

Hugot – Handbook Of Cane Sugar Engineering 3rd ed Page 858

$$S = 1{,}7 \frac{ft^2}{ton} \times 1.666{,}2198 \frac{kg}{jam} \times \frac{1\ ton}{1000\ kg} = 2{,}8326\ ft^2$$

Diameter kondensor

$$S = \frac{\pi}{4} \times ID^2$$

$$2{,}8326\ ft^2 = \frac{3{,}14}{4} \times ID^2$$

$$ID = \left(\frac{2{,}8326\ ft^2}{0{,}785}\right)^{0,5} = 1{,}8996\ ft = 0{,}5790\ m = 22{,}7952\ in$$

Tinggi kondensor

Dari Hugot‘s tabel 40.1 hal. 858, bahwa untuk *rate* penguapan sejumlah 3673,348 lb uap/jam diperoleh nilai H atau tinggi kondensor sebesar 2.5 m atau 8.202 ft atau 98.425 in.

P_d = 14,6959 psi

R = 11,3976 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

Tinggi *conical*

Alas dari *barometric condenser* berbentuk kerucut dengan sudut 60°

$$H_c = \frac{1}{2} \times D \times \tan 60°$$

$$H_c = \frac{1}{2} \times 0{,}5790\ m \times 1{,}73 = 0{,}5008\ m = 1{,}6426\ ft = 19{,}7165\ in$$

Tebal *conical*

$$t_c = \frac{PD}{2(SE - 0{,}6P)\cos 60°} + C$$ Walas - Chemical Process Equipment, Table 18.4

$$t_c = \frac{14{,}6959\ psi \times 22{,}7952\ in}{2(17500\ psi \times 0{,}85 - 0{,}6 \times 14{,}6959\ psi)0{,}5} + 0{,}02\ in/tahun \times 10\ tahun$$

$$t_c = 0{,}2\ in = 0{,}0051\ m = 0{,}0167\ ft = 5{,}0800\ mm$$

Tebal dinding kondensor

$$t_d = \frac{PR}{SE - 0{,}6P} + C$$ *Walas - Chemical Process Equipment, Table 18.4, Page 658*

$$t_d = \frac{14{,}6959\ psi \times 11{,}3976\ in}{17500\ psi \times 0{,}85 - 0{,}6 \times 14{,}6959\ psi} + 0{,}02\ in/tahun \times 10\ tahun = 0{,}2113\ in$$

$$= 0{,}0054\ m$$

$$= 0{,}0177\ ft$$

$$= 5{,}3670\ mm$$

Tebal Tutup

Tutup *barometric condenser* berbentuk datar.

$$t_f = D\sqrt{\frac{0{,}3\ P}{S}} + C$$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$$t_f = 22{,}7952\ in\sqrt{\frac{0{,}3 \times 14{,}6959\ psi}{17500\ psi}} + 0{,}02\ in/tahun \times 10\ tahun = 0{,}5618\ in$$

$$= 0{,}0143\ m$$

$$= 0{,}0469\ ft$$

$$= 14{,}2697\ mm$$

6) *Condensor* (CD-1061)

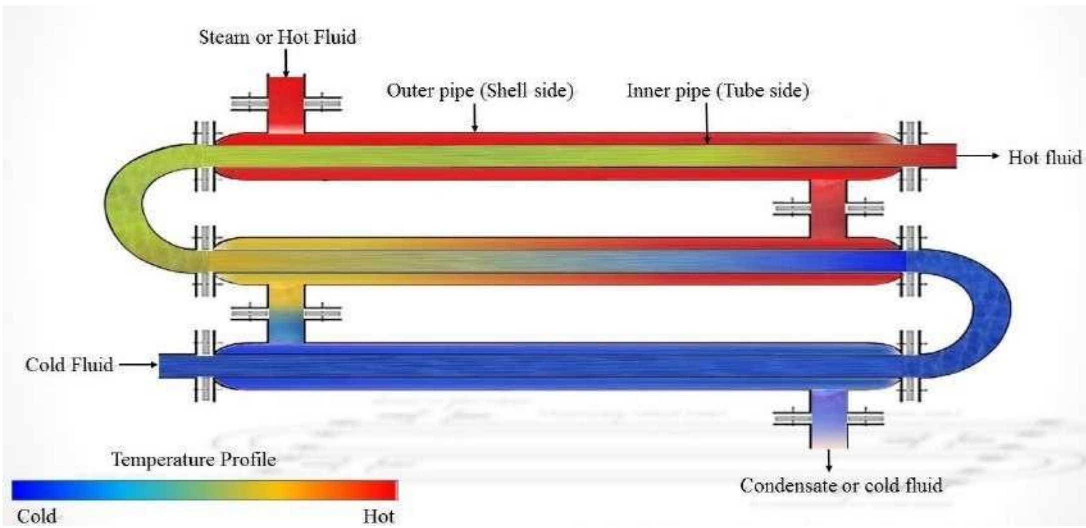
Fungsi : Untuk mendinginkan dan merubah fasa dari produk atas *deodorizer*

Tipe : *Double Pipe*

Bahan konstruksi : *Dupllex Stainless steel* Tipe-2205

Jumlah : 1 unit

Fasa : Cair



Gambar LC-7. *Condensor*

Data:

- Laju alir *hot fluid* (*top product*): 188,4572 kg/jam : 415,4727 lb/jam
- Laju alir *cold fluid* (*cooling water*): 1.801,0493 kg/jam : 3.970,5933 lb/jam
- Q : 18.010,4934 kkal/jam : 71.465,6378 btu/jam
- Tekanan : 1 atm
- T_1 : 196,47 ^oC : 385,464 ^oF
- T_2 : 30 ^oC : 86 ^oF
- t_1 : 28 ^oC : 82,4 ^oF
- t_2 : 38 ^oC : 100,4 ^oF

1. Menentukan Jenis *Cooler*

a. Menghitung LMTD

Hot fluid		*Cold Fluid*	*Difference*	
385,646	***High Temperatur***	100,4	285,246	Δt_2
86	***Low Temperatur***	82,4	3,6	Δt_1
			281,646	$\Delta t_2 - \Delta t_1$

$$LMTD = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln\left(\frac{T_1 - t_2}{T_2 - t_1}\right)}$$ DQ Kern, Pers 6.17 hal 117

$$LMTD = \frac{(385{,}464\ °F - 100{,}4\ °F) - (86\ °F - 82{,}4\ °F)}{\ln\left(\frac{385{,}464\ °F - 100{,}4\ °F}{86\ °F - 82{,}4\ °F}\right)}$$

$$= 64{,}4145\ °F$$

b. Luas Area Perpindahan Panas

Diketahui viskositas *hot fluid* : 8,2309 cP

Berdasarkan *Table 8 - DQ Kern Page 840*, diperoleh :

Coolers

Hot fluid	Cold fluid	Overall U_D
Water	Water	250–500§
Methanol	Water	250–500§
Ammonia	Water	250–500§
Aqueous solutions	Water	250–500§
Light organics*	Water	75–150
Medium organics†	Water	50–125
Heavy organics‡	Water	5–75‖
Gases	Water	2–50¶
Water	Brine	100–200
Light organics	Brine	40–100

Maka dipilih U_d = 40 Btu/jam ft^2 °F

Maka,

$$A = \frac{Q}{U_d \times LMTD}$$ DQ. Kern Pers 7.42 Hal 144

$$A = \frac{71.465,6378 \text{ btu/jam}}{40 \text{ Btu/jam ft}^2 \text{ °F} \times 64,4145 \text{ °F}}$$

$A = 27,7366 \text{ ft}^2$

Karena nilai A < 200 ft^2 maka tipe *heat exchanger* yang digunakan adalah *double pipe* (*DQ Kern Page 103*)

2. Pemilihan Ukuran *Double Pipe*

Berdasarkan *Table 6.2 DQ. Kern Page 110* maka dipilih ukuran *double pipe* berikut ini.

	Outer pipe	***Inner Pipe***	**Satuan**
IPS	3	2	In
Sch	40	40	
OD	3,5	2,38	In
ID	3,068	2,067	In
a''	0,917	0,622	ft^2/ft

3. Menentukan *caloric temperature*

$T_{av} = \frac{T_1 + T_2}{2}$ DQ.Kern Hal 113

$T_{av} = \frac{196,47 \text{ °F} + 86 \text{ °F}}{2}$

$= 235,823\text{°F}$

$t_{av} = \frac{t_1 + t_2}{2}$ DQ.Kern Hal 113

$t_{av} = \frac{82,4 \text{ °F} + 100,4 \text{ °F}}{2}$

$= 91 \text{ °F}$

Annulus (Top product)	***Inner Pipe (Cooling Water)***
4. *Flow area* $a_a = \frac{\pi(D_2^2 - D_1^2)}{4}$ DQ. Kern Pers 6.3 $a_a = \frac{3,14\ ((0,2557\ ft)^2 - (0,1983\ ft)^2)}{4}$ $= 0,0205\ ft^2$ *Equivalent diameter* $D_e = \frac{(D_2^2 - D_1^2)}{D_1}$ DQ. Kern Hal 111 $D_e = \frac{(0,2557\ ft)^2 - (0,1983\ ft)^2}{0,1983\ ft}$ $= 0,1314\ ft$	4. *Flow area* $a_p = \frac{\pi(D^2)}{4}$ DQ. Kern Hal 111 $a_p = \frac{3,14\ ((0,1723\ ft)^2)}{4}$ $= 0,1753\ ft^2$
5. Laju alir massa $G_a = \frac{W}{a_a}$ DQ. Kern Hal 114 $G_a = \frac{415,4727\ lb/jam}{0,0205\ ft^2}$ $= 20.266,9610\ lb/jam\ ft^2$	5. Laju alir massa $G_p = \frac{W}{a_p}$ DQ. Kern Hal 114 $G_p = \frac{3.970,5933\ lb/jam}{0,1353\ ft^2}$ $= 29.346,5876\ lb/jam\ ft^2$
6. Bilangan Reynold T_{av} = 235,823 °F μ *top product* = 3 cP = 7,2576 lb/ft jam DQ. Kern Hal 825	6. Bilangan Reynold T_{av} = 91 °F μ *Cooling water* = 0,8 cP = 1,9354 lb/ft jam DQ. Kern Hal 823

	Sp gr at 300°F	X	Y
Lauric	0.792	10.1	23.1
Oleic	0.799	10.0	25.2
Palmitic	0.786	9.2	25.9
Stearic	0.789	10.5	25.5

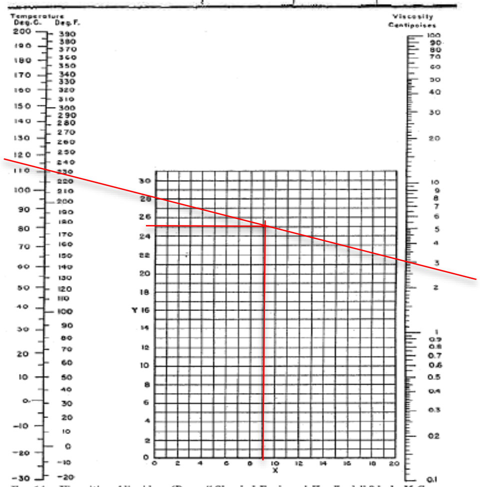


Fig. 14. Viscosities of liquids. (Perry, "Chemical Engineers' Handbook," 3d ed., McGraw

$$R_{ea} = \left(\frac{D_e \times G_a}{\mu}\right) \quad \text{DQ. Kern Hal 114}$$

$$R_{ea} = \left(\frac{0{,}1314 \text{ ft} \times 20.266{,}9610 \text{ lb/jam ft}^2}{7{,}2576 \text{ lb/ft jam}}\right)$$

$= 366{,}9365$

7. jH

jH = 15 DQ. Kern Hal 834

Ethyl chloride	14.8	6.0	Toluene	13.7	10.4
Ethyl ether	14.5	5.3	Trichloroethylene	14.8	10.5
Ethyl formate	14.2	8.4	Turpentine	11.5	14.9
Ethyl iodide	14.7	10.3	Vinyl acetate	14.0	8.8
Ethylene glycol	6.0	23.6	Water	10.2	13.0
Formic acid	10.7	15.8	Xylene, ortho	13.5	12.1
Freon-11	14.4	9.0	Xylene, meta	13.9	10.6
Freon-12	16.8	5.6	Xylene, para	13.9	10.9

* From Perry, J. H., "Chemical Engineers' Handbook," 3d ed., McGraw-Hill Book Company, Inc.,

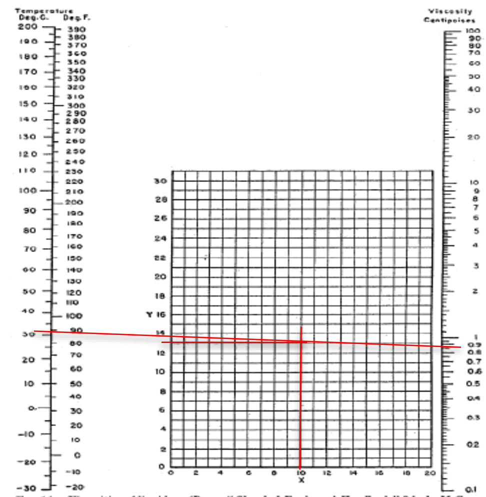


Fig. 14. Viscosities of liquids. (Perry, "Chemical Engineers' Handbook," 3d ed., McGraw

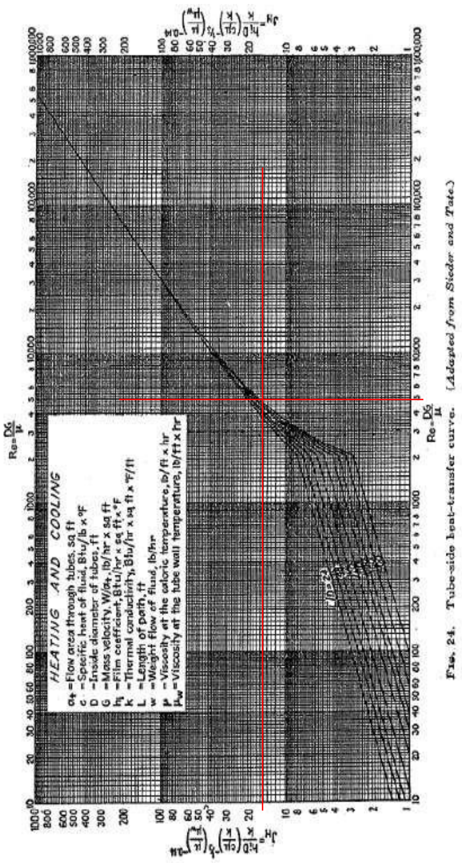
$$R_{ep} = \left(\frac{D \times G_p}{\mu}\right) \quad \text{DQ. Kern Hal 114}$$

$$R_{ep} = \left(\frac{0{,}1723 \text{ ft} \times 29.346{,}5876 \text{ lb/jam ft}^2}{1{,}9354 \text{ lb/ft jam}}\right)$$

$= 6.320{,}5213$

7. jH

jH = 25 DQ. Kern Hal 834



8. Konduktivitas dan kapasitas panas

Pada t_{av}= 235,823 °F

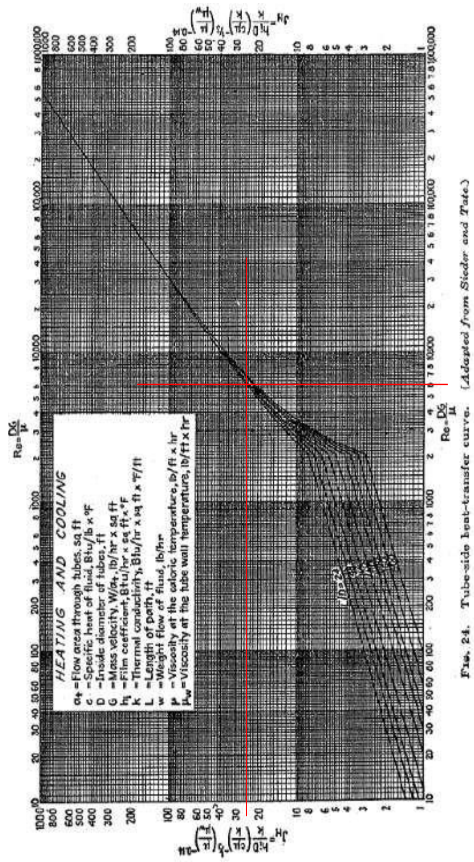
c = 0,121 btu/lb °F

k = 0,0835 btu/(hr)(ft^2)(°F)

DQ. Kern Hal 800

$$\left(\frac{c\,\mu}{k}\right)^{1/3} = \left(\frac{0{,}121\,\frac{\text{btu}}{\text{lb °F}} \times 7{,}2576\,\frac{\text{Ib}}{\text{hr ft}}}{0{,}0835\,\frac{\text{Btu}}{(\text{hr})\,(\text{ft}^2)(\text{°F/ft})}}\right)^{\frac{1}{3}}$$

= 2,1909 ft



8. Konduktivitas dan kapasitas panas

Pada t_{av}= 91 °F

c = 0,1 btu/lb °F

k = 0,3560 btu/(hr)(ft^2)(°F)

DQ. Kern Hal 800

$$\left(\frac{c\,\mu}{k}\right)^{1/3} = \left(\frac{0{,}1\,\frac{\text{btu}}{\text{lb °F}} \times 1{,}9354\,\frac{\text{Ib}}{\text{hr ft}}}{0{,}3560\,\frac{\text{Btu}}{(\text{hr})\,(\text{ft}^2)(\text{°F/ft})}}\right)^{\frac{1}{3}}$$

= 0,8162 ft

9. h_o

$$h_o = jH\frac{k}{D}\left(\frac{c\,\mu}{k}\right)^{\frac{1}{3}}\left(\frac{\mu}{\mu_w}\right)^{0,14} \quad \text{pers 6.15a DQ Kern}$$

$$h_o = (15)\frac{0,0835\,\frac{btu}{(hr)\,(ft^2)(°F/ft)}}{0,1314\ ft}(2,1909\ ft)(1)$$

$= 20,8836\ btu/(hr)(ft^2)(°F)$

10. Koreksi h_i

$$h_{io} = h_i\frac{ID}{OD} \quad \text{pers 6.15 DQ Kern}$$

$$h_{io} = 42,1601\ \frac{btu}{(hr)\ (ft^2)(°F)}\ \frac{0,1723\ ft}{0,1983\ ft}$$

$= 36,6323\ btu/(hr)(ft^2)(°F)$

Temperatur Dinding

$$t_w = t_{avg} + \frac{h_o}{h_{io}+h_o} \times (T_{avg} - t_{avg})$$

$$t_w = 91\ °F + \frac{20,8836\ btu/hr\ ft^2\ °F}{(36,6323 + 20,8836)\ btu/(hr)(ft^2)(°F)} \times (235-91)°F$$

$= 144\ °F$

Pada $t_w = 144\ °F$

$\mu = 1,8\ lb/ft\ jam$

Maka,

$$\phi_p = \left(\frac{\mu}{\mu_w}\right)^{0,14}$$

$$\phi_p = \left(\frac{7,\ 2576\ lb/ft\ jam}{10,3\ lb/ft\ jam}\right)^{0,14}$$

$= 0,9522$

h_o sebenarnya $= 20,8836\ btu/(hr)(ft^2)(°F) \times 0,9522$

$= 19,8854\ btu/(hr)(ft^2)(°F)$

9. h_i

$$h_i = jH\frac{k}{D}\left(\frac{c\,\mu}{k}\right)^{\frac{1}{3}}\left(\frac{\mu}{\mu_w}\right)^{0,14} \quad \text{pers 6.15a DQ Kern}$$

$$h_i = (25)\frac{0,3560\,\frac{btu}{(hr)\,(ft^2)(°F/ft)}}{0,1723\ ft}(0,8162\ ft)(1)$$

$= 42,1601\ btu/(hr)(ft^2)(°F)$

10. Koreksi h_i

$$h_{io} = h_i\frac{ID}{OD} \quad \text{pers 6.15 DQ Kern}$$

$$h_{io} = 42,1601\ \frac{btu}{(hr)\ (ft^2)(°F)}\ \frac{0,1723\ ft}{0,1983\ ft}$$

$= 36,6323\ btu/(hr)(ft^2)(°F)$

Temperatur Dinding

$$t_w = t_{avg} + \frac{h_o}{h_{io}+h_o} \times (T_{avg} - t_{avg})$$

$$t_w = 91\ °F + \frac{20,8836\ btu/hr\ ft^2\ °F}{(36,6323 + 20,8836)\ btu/(hr)(ft^2)(°F)} \times (235-91)°F$$

$= 144\ °F$

Pada $t_w = 144\ °F$

$\mu = 1,8\ lb/ft\ jam$

Maka,

$$\phi_p = \left(\frac{\mu}{\mu_w}\right)^{0,14}$$

$$\phi_p = \left(\frac{1,9354\ lb/ft\ jam}{1,8\ lb/ft\ jam}\right)^{0,14}$$

$= 1,0102$

h_{io} sebenarnya $= 36,6323\ btu/(hr)(ft^2)(°F) \times 1,0102$

$= 37,0059\ btu/(hr)(ft^2)(°F)$

11. Clean overall coefficient

$$U_c = \frac{h_{io} \times h_o}{h_{io} + h_o} \qquad \text{Pers 6.7 DQ Kern}$$

$$U_c = \frac{19{,}8854 \frac{btu}{hr\ ft^2 °F} \times 37{,}0059 \frac{btu}{hr\ ft^2 °F}}{19{,}8854 \frac{btu}{hr\ ft^2 °F} + 37{,}0059 \frac{btu}{hr\ ft^2 °F}} = 12{,}9348 \frac{btu}{hr\ ft^2 °F}$$

12. Design overall coefficient

$$\frac{1}{U_d} = \frac{1}{U_c} + R_d \qquad \text{Pers 6.10 DQ Kern}$$

$$\frac{1}{U_d} = \frac{1}{12{,}9348 \frac{btu}{hr\ ft^2 °F}} + 0{,}001\ ft^2\ hr\ °F/btu$$

$$U_d = 12{,}7714 \frac{btu}{hr\ ft^2 °F}$$

13. Surface area required

$$A = \frac{Q}{U_d \times LMTD} \qquad \text{DQ. Kern Pers 7.42 Hal 144}$$

$$A = \frac{71.465{,}6378\ btu/jam}{12{,}7714\ btu/jam\ ft^2\ °F \times 64{,}4145°F}$$

$$A = 86{,}8711\ ft^2$$

14. Menghitung jumlah *hairpin*

Required length $= \frac{A}{a''}$

Required length $= \frac{86{,}8711\ ft^2}{0{,}622\ ft^2/ft}$

Required length = 139,6641 ft

Digunakan Panjang pipa untuk *double pipe heat exchanger* : 15 ft

1 *hairpin* terdiri dari 2 pipa, maka jumlah *hairpin* yang diperlukan adalah :

$$Hairpin = \frac{L}{2 \times L_H}$$

$$Hairpin = \frac{139{,}6641 \text{ ft}}{2 \times 15 \text{ ft}}$$

Hairpin = 4,6555

≈ 5

Koreksi Panjang pipa

L koreksi = 2 × L *Hairpin* × Banyak *Hairpin*

L koreksi = 2 × 15 ft × 5

L koreksi = 150 ft

15. Actual design overall coefficient

actual surface = *required length* × a"

actual surface = 150 ft × 0,622 ft^2/ft = 93,30 ft^2

$$U_d \textit{ actual} = \frac{Q}{A \times LMTD}$$

$$U_d \textit{actual} = \frac{71.465{,}6378 \text{ btu/jam}}{93{,}30 \text{ ft}^2 \times 64{,}4145\ °F}$$

U_d *actual* = 11,8914 btu/jam ft^2 °F

Asumsi benar karena U_d *actual* < U_d desain

R_d sebenarnya

$$R_d = \frac{U_c - U_d}{U_c \times U_d}$$

$$R_d = \frac{12{,}9348 \text{ btu/jam ft}^2\ °F - 11{,}8914 \text{ btu/jam ft}^2\ °F}{12{,}9348 \text{ btu/jam ft}^2\ °F \times 11{,}8914 \text{ btu/jam ft}^2\ °F}$$

R_d = 0,0068 ft^2 jam °F/btu

R_d yang diperlukan = 0,001 ft^2 jam °F/btu

R_d sebenarnya > R_d yang diperlukan (memenuhi)

16. Pressure drop

Annulus (Steam)	***Inner Pipe (PFAD)***
1. $D_e' = D_2 - D_1$ Pers 6.4 DQ Kern	1. Re_p = 6.320,5213 (turbulen)
D_e' = 0,2557 ft - 0,1983 ft	*Fanning factor* untuk turbulen :
D_e' = 0,0574 ft	$f = 0,0035 + \frac{0,264}{(DG/\mu)^{0,42}}$ Pers 3.47b DQ Kern
$Re_a' = \frac{D_e' \times G_a}{\mu}$	$f = 0,0035 + \frac{0,264}{(6.320,5213)^{0,42}}$
$Re_a' = \frac{0,0574 \text{ ft} \times 20.266,9610 \text{ lb/hr ft}^2}{7,2576 \text{ lb/ft hr}}$	f = 0,0094
Re_a' = 160,2904 (laminar)	2. $\Delta F_p = \frac{4 \times f \times Gp^2 \times L}{2 \times g \times \rho^2 \times D_e}$ Pers 6.14 DQ Kern
Fanning factor untuk laminar :	$g = 4,18 \times 10^8 \text{ft/hr}^2$
$f = \frac{16}{(DG/\mu)}$ Pers 3.46 DQ Kern	$\rho = 62,4300 \text{ lb/ft}^3$
$f = \frac{16}{160,2904}$	$\Delta F_p = \frac{4 \times 0,0094 \times (29.346,5876 \text{ lb/hr ft})^2 \times 150 \text{ ft}}{2 \times 4,18 \times 10^8 \text{ft/hr} \times (62,4300 \text{ lb/ft}^3)^2 \times 0,1723 \text{ ft}}$
f = 0,0998	ΔF_p = 0,0094 ft
2. $\Delta F_a = \frac{4 \times f \times Ga^2 \times L}{2 \times g \times \rho^2 \times D_e}$ Pers 6.14 DQ Kern	3. $\Delta P_p = \frac{(\Delta F_p)\rho}{144}$ Pers 3.45 DQ Kern
$g = 4,18 \times 10^8 \text{ft/hr}^2$	$\Delta P_a = \frac{(0,0094 \text{ ft})\ 62,4300 \text{ lb/ft}^3}{144}$
$\rho = 46,8460 \text{ lb/ft}^3$	ΔP_a = 0,0041 psi
$\Delta F_a = \frac{4 \times 0,0998 \times (20.266,9610 \text{ lb/hr ft})^2 \times 150 \text{ ft}}{2 \times 4,18 \times 10^8 \text{ft/hr} \times (46,8460 \text{ lb/ft}^3)^2 \times 0,0574 \text{ ft}}$	ΔP_a yang diizinkan=10 psi
ΔF_a = 0,2336 ft	0,0041 psi < 10 psi (Memenuhi)
3. $V = \frac{G}{3600\rho}$	
$V = \frac{20.266,9610 \text{ lb/hr ft}^2}{3600 \times 46,8460 \text{ lb/ft}^3}$	
V = 0,1202 ft/s	

$\Delta F_l = \dfrac{V^2}{2g}$ $\Delta F_l = \dfrac{(0,1202\ ft/s)^2}{2 \times 32,2\ ft/s^2}$ $\Delta F_l = 0,0002$ ft 4. $\Delta P_a = \frac{(\Delta Fa + \Delta F1)\rho}{144}$ Pers 3.45 DQ Kern $\Delta P_a = \dfrac{(0,2336\ ft + 0,0002\ ft)\ 46,8460\ lb/ft^3}{144}$ ΔP_a= 0,0761 psi ΔP_a yang diizinkan=10 psi 0,0761 psi < 10 psi (Memenuhi)	

7) *Accumulator* (AC-1071)

Fungsi : Tempat untuk menampung kondensat dari *condensor*

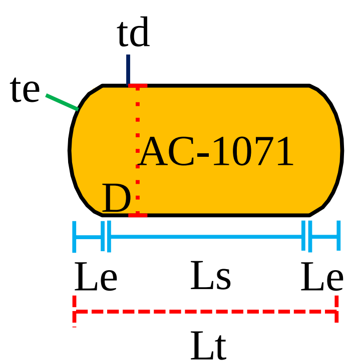
Tipe : Silinder horizontal dengan kedua ujung *elipsoidal*

Bahan konstruksi : *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*

Jumlah : 1 unit

Sifat bahan : Tidak volatil dan korosif pada baja ringan

Fasa : Cair



Gambar LC-8. *Accumulator*

Data:

- Laju alir umpan : 188,4570 kg/jam : 415,4723 lb/jam
- Densitas campuran : 789,3450 kg/m^3 : 49,2794 lb/ft^3
- Tekanan : 1 atm
- Viskositas Campuran : 3,1120 cP : 0,0023 lb/ft.s
- Lama Penyimpanan : 0,5 jam

1. Kapasitas *Accumulator*

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

$$V_p = \frac{188{,}4570 \text{ kg/jam} \times 0{,}5 \text{ jam}}{789{,}3450 \text{ kg/m}^3}$$

$$V_p = 0{,}1194 \text{ m}^3$$

$$= 4{,}2165 \text{ ft}^3$$

$$= 7.286{,}2350 \text{ in}^3$$

$$= 31{,}5421 \text{ gal}$$

Dengan Mempertimbangkan faktor keamanan 15 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$$V_p = 0{,}85\ V_t$$

$$V_t = \frac{V_p}{0{,}85}$$

$$V_t = \frac{0{,}1194 \text{ m}^3}{0{,}85}$$

$$V_t = 0{,}1405 \text{ m}^3$$

$$= 4{,}9616 \text{ ft}^3$$

$$= 8.573{,}8360 \text{ in}^3$$

$$= 37{,}1162 \text{ gal}$$

2. Dimensi Tangki

a. Volume Silinder

$V_s = \frac{\pi}{4} \times D_t^2 \times L_s$ Dengan $L_s = 3\ D_t$

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

$V_s = 2{,}355\ D_t^3$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times L_e$ Dengan $L_e = 1/4\ D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0{,}1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + 2\ V_e$

$V_t = 2{,}355\ D_t^3 + 2\ (0{,}1308\ D_t^3)$

$V_t = 2{,}6166\ D_t^3$

$D_t^3 = \frac{V_t}{2{,}6166}$

$D_t^3 = \frac{0{,}1405\ m^3}{2{,}6166}$

$D_t = \sqrt[3]{\frac{0{,}1405\ m^3}{2{,}6166}}$

$D_t = 0{,}3773$ m

= 1,2375 ft

= 14,8543 in

d. Panjang *Accumulator*

$L_s = 3\ D_t$

$L_s = 3 \times 0{,}3773$ m

$L_s = 1{,}1319$ m

$= 3{,}7126$ ft

$= 44{,}5629$ in

e. Panjang *Ellipsoidal*

$L_e = 1/4\ D_t$

$L_e = 1/4 \times 0{,}3773$ m

$L_e = 0{,}0943$ m

$= 0{,}3093$ ft

$= 3{,}7126$ in

f. Panjang Total *Accumulator*

$L_t = L_s + (2\ L_e)$

$L_t = 1{,}1319\ m + (2 \times 0{,}0943\ m)$

$L_t = 1{,}3205$ m

g. Tinggi Cairan

$$H_c = \frac{V_p \times D}{V_t}$$

$$H_c = \frac{0{,}1194\ m^3 \times 0{,}3773\ m}{0{,}1405\ m^3}$$

$H_c = 0{,}3206$ m

$= 1{,}0516$ ft

$= 12{,}6220$ in

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

P_c = 789,3450 kg/m^3× 9,81 m/s^2 × 0,3206 m

P_c = 2.482,5862 kg.m/s^2

= 0,0241 atm

= 0,3542 psi

i. Tekanan Desain

P_d = P_{op}+ P_c

P_d = 1 atm + 0,0241 atm

P_d = 1,0241 atm

= 15,0501 psi

P_d = 15,0501 psi

R = 7,4272 in

S = 18700 psi (*Peters* - *Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding *Accumulator*

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment*, *Table 18.4*, *Page 658*)

$$t_d = \frac{15,0501 \text{ psi} \times 7,4272 \text{ in}}{18700 \text{ psi} \times 0,85 - 0,6 \times 15,0501 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2070 in

= 0,0053 m

= 0,0174 ft

= 5,2578 mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0,2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{15,0501 \text{ psi} \times 0,3773 \text{ in}}{2 \times 18700 \text{ psi} \times 0,85 - 0,2 \times 15,0501 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2070 in

= 0,0053 m

= 0,0174 ft

= 5,2578 mm

8) *Reboiler* (RB-1081)

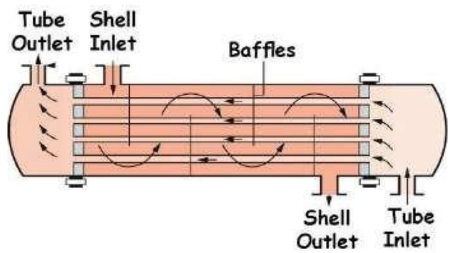
Fungsi : Untuk memanaskan kembali umpan pada unit *deodorizer*

Tipe : *Sheel and tube*

Bahan konstruksi : *Dupllex Stainless steel* Tipe-2205

Jumlah : 1 unit

Fasa : Cair



Gambar LC-9. *Reboiler*

Data:

- Laju alir *hot fluid* (*Steam*) : 334,5085 kg/jam : 737,4574 lb/jam
- Laju alir *cold fluid* (*Top produt*) : 188,4572 kg/jam : 415,4727 lb/jam
- Q : 140.228,2817 kkal/jam : 556.425,8218 btu/jam
- Tekanan : 1 atm
- T_1 : 242 ^oC : 467,6 ^oF
- T_2 : 242 ^oC : 467,6 ^oF
- t_1 : 30 ^oC : 86 ^oF
- t_2 : 226 ^oC : 438,8 ^oF

1. Menentukan Jenis *Reboiler*

a. Menghitung LMTD

Hot fluid		***Cold Fluid***	***Difference***	
467,6	***High Temperatur***	438,8	28,8	**Δt_2**
467,6	***Low Temperatur***	86	381,6	**Δt_1**
			352,8	**Δt_2-Δt_1**

$$LMTD = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln\left(\frac{T_1 - t_2}{T_2 - t_1}\right)}$$ DQ Kern, Pers 6.17 hal 117

$$LMTD = \frac{(467,6\ °F - 438,8\ °F) - (467,6\ °F - 86\ °F)}{\ln\left(\frac{467,6\ °F - 438,8\ °F}{467,6\ °F - 86\ °F}\right)}$$

$$= 136,5326\ °F$$

b. Luas Area Perpindahan Panas

Diketahui viskositas *cold fluid* : 8,2309 cP

Berdasarkan *Table 8 - DQ Kern Page 840,* diperoleh :

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¶

Maka dipilih U_d = 20 Btu/jam ft^2 °F

Maka,

$$A = \frac{Q}{U_d \times LMTD}$$ DQ. Kern Pers 7.42 Hal 144

$$A = \frac{556.425,8218\ btu/jam}{20\ Btu/jam\ ft^2\ °F \times 136,5326\ °F}$$

A = 203,7703 ft^2

Karena nilai A > 200 ft^2 maka tipe *heat exchanger* yang digunakan adalah *Shell and tube* (*DQ Kern Page 103*)

2. Spesifikasi *shell and tube*

Berdasarkan *Table 6.2 DQ. Kern Page 110* maka dipilih ukuran *double pipe* berikut ini.

OD (in)	**a" (ft^2) Tube**	**BWG**	**L (ft)**
1	0,2618	13	15

3. Menentukan *caloric temperature*

$T_{av} = \frac{T_1 + T_2}{2}$ DQ.Kern Hal 113

$T_{av} = \frac{467{,}6\ °F + 467{,}6\ °F}{2}$

$= 467{,}6\ °F$

$t_{av} = \frac{t_1 + t_2}{2}$ DQ.Kern Hal 113

$t_{av} = \frac{86\ °F + 438{,}8\ °F}{2}$

$= 262{,}4\ °F$

4. Menentukan jumlah *tube*

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

$$N_t = \frac{203{,}7703}{15 \times 0{,}2618} = 51{,}8896 \approx 52$$

Berdasarkan Tabel 9, untuk jumlah tube 52 diperoleh spesifikasi perancangan Heat Exchanger tipe *Shell and Tube* dengan data sebagai berikut.

Shell side		***Tube side***	
ID (in)	13,25	*Number*	52
Baffle space (in)	3,313	*Length*	15
Passes	1	*OD (in)*	1
		ID (in)	0,87
		BWG	13
		pitch (in) - square	1,25
Clearance, C'	0,25	*Passes*	4

Tube side (Top product)	*Shell side (Steam)*
5. *Flow area per tube* a' tube = 0,515 in^{2}N $a_t = \frac{N_t \times a'_t}{144 \times \eta}$ DQ. Kern Hal 150 $a_t = \frac{52 \times 0,515\ in^2}{144 \times \eta} = 0,0465\ ft^2$	5. *Flow area per shell* $a_s = ID \times \frac{C'' \times B}{144 \times P_t}$ DQ. Kern Hal 150 $a_s = 13,25\ in \times \frac{0,25 \times 3,313\ in}{144 \times 1,25\ in}$ $a_s = 0,0610\ ft^2$
6. Laju alir massa $G_t = \frac{W}{a_t}$ DQ. Kern Hal 114 $G_t = \frac{415,4727\ lb/jam}{0,0465\ ft^2}$ $= 8.934,8968\ lb/jam\ ft^2$	6. Laju alir massa $G_s = \frac{W}{a_s}$ DQ. Kern Hal 114 $G_s = \frac{737,4574\ lb/jam}{0,0610\ ft^2}$ $= 12.089,4656\ lb/jam\ ft^2$
7. Bilangan Reynold T_{av} = 262,4 °F μ *top product* = 1,1 cP = 2,6611 lb/ft jam DQ. Kern Hal 823 $R_{et} = (\frac{D_t \times G_t}{\mu})$ DQ. Kern Hal 41 $R_{et} = (\frac{0,0725\ ft \times 8.934,8968\ lb/jam\ ft^2}{2,6611\ lb/ft\ jam})$ = 243,4257	7. Bilangan Reynold T_{av} = 467,6 °F μ *steam* = 0,017 cP = 0,0411 lb/ft jam DQ. Kern Hal 825 $d_e = \frac{4 \times (P_t^2 - \pi\ OD^2/4)}{\pi \times OD}$ $d_e = \frac{4 \times (1,25^2 - 3,14 \times 1^2/4)}{3,14 \times 1} = 0,9904\ in$ = 0,0825 ft $R_{es} = (\frac{d_e \times G_s}{\mu})$ DQ. Kern Hal 114 $R_{es} = (\frac{0,0825\ ft \times 12.089,4656\ lb/jam\ ft^2}{0,0411\ lb/ft\ jam})$ = 24.267,1755
8. jH L/D = 206,8966 jH = 8 DQ. Kern Hal 834	

9. Konduktivitas dan kapasitas panas

Pada t_{av}= 262,4 °F

c = 0,653 btu/lb °F

k = 0,0835 btu/(hr)(ft^2)(°F)

DQ. Kern Hal 800

$$\left(\frac{c\,\mu}{k}\right)^{1/3} = \left(\frac{0{,}653 \frac{btu}{lb\ °F} \times 2{,}6611 \frac{lb}{hr\ ft}}{0{,}0835 \frac{Btu}{(hr)\ (ft^2)(°F/ft)}}\right)^{\frac{1}{3}}$$

$$= 2{,}7478\ ft$$

10. h_i

$$h_o = jH \frac{k}{D} \left(\frac{c\,\mu}{k}\right)^{\frac{1}{3}} \phi_t \quad \text{pers 6.15a DQ Kern}$$

$$h_o = (8) \frac{0{,}0835 \frac{btu}{(hr)\ (ft^2)(°F/ft)}}{0{,}0725\ ft} (2{,}1909\ ft)(1)$$

$$= 25{,}3177\ btu/(hr)(ft^2)(°F)$$

Karena viskositas rendah, maka diasumsikan Ǿ = 1

11. Koreksi h_i

$$h_{io} = h_i \frac{ID}{OD} \quad \text{pers 6.15 DQ Kern}$$

$$h_{io} = 25{,}3177 \frac{btu}{(hr)\ (ft^2)(°F)} \frac{0{,}0725\ ft}{0{,}0833\ ft}$$

$$= 22{,}0352\ btu/(hr)(ft^2)(°F)$$

8. h_o

Steam yang mengalami perubahan fasa tanpa perubahan suhu maka $h_i = h_o = h_{io}$ (DQ. Kern Hal 163-164)

Maka, h_o = 1500 btu/hr ft^2 °F

12. Clean overall coefficient

$$U_c = \frac{h_{io} \times h_o}{h_{io} + h_o} \quad \text{Pers 6.7 DQ Kern}$$

$$U_c = \frac{22{,}0352\frac{btu}{hr\ ft^2°F} \times 1500\frac{btu}{hr\ ft^2°F}}{22{,}0352\frac{btu}{hr\ ft^2°F} + 1500\frac{btu}{hr\ ft^2°F}} = 21{,}7162\ \frac{btu}{hr\ ft^2°F}$$

13. Design overall coefficient

$$U_d = \frac{Q}{A \times LMTD}$$ DQ. Kern Pers 7.42 Hal 144

$$U_d = \frac{556.425{,}8218\ btu/jam}{203{,}7703\ ft^2 \times 136{,}5326\ °F}$$

$$U_d = 20\ \frac{btu}{hr\ ft^2°F}$$

R_d sebenarnya

$$R_d = \frac{U_c - U_d}{U_c \times U_d}$$

$$R_d = \frac{21{,}7162\ btu/jam\ ft^2\ °F - 20\ btu/jam\ ft^2\ °F}{21{,}7162\ btu/jam\ ft^2\ °F \times 20\ btu/jam\ ft^2\ °F}$$

R_d = 0,0040 ft^2 jam °F/btu

R_d yang diperlukan = 0,001 ft^2 jam °F/btu

R_d sebenarnya > R_d yang diperlukan (memenuhi)

14. Pressure drop

Tube side (Top product)	***Inner Pipe (Steam)***
1. Untuk NRe = 243,4257 f = 0,002 DQ Kern Halaman 839 S = 0,96 DQ Kern Halaman 839 2. $\Delta P_{t2} = \frac{f \times Gt^2 \times L \times n}{5{,}22 \times 10^{10} D_{e's} \times \emptyset_t}$ $\Delta P_{t2} = \frac{0{,}002 \times 8.934{,}8968 \text{ lb/jam ft}^2 \times 1 \times 4}{5{,}22 \times 10^{10} \times 0{,}0725 \text{ ft} \times 0{,}96 \text{ ft} \times 1}$ ΔP_{t2} = 0,0026 psi 3. $\frac{V^2}{2g} = 0{,}04$ $\Delta P_{t1} = \frac{4n}{s} \times \frac{V^2}{2g}$ $\Delta P_{t1} = \frac{4 \times 4}{0{,}96} \times 0{,}04 = 0{,}6667$ psi 4. $\Delta P_T = \Delta P_{t1} + \Delta P_{t2}$ ΔP_T= 0,6667 psi + 0,0026 psi ΔP_T= 0,6693 psi ΔP_T yang diizinkan=10 psi 0,0,6693 psi < 10 psi (Memenuhi)	1. Untuk NRe = 24.267,1755 f = 0,002 DQ Kern Halaman 839 S = 0,96 DQ Kern Halaman 839 D_s = 1,1042 ft *2. No of crosses* $N + 1 = \frac{12\ L}{B}$ DQ Kern Halaman 151 $N + 1 = \frac{12 \times 15 \text{ ft}}{3{,}313 \text{ ft}} = 54{,}3314$ 3. $\Delta P_s = \frac{f \times Gs^2 \times D_s \times (N+1)}{5{,}22 \times 10^{10} D_{e's} \times \emptyset_t}$ $\Delta P_s = \frac{0{,}002 \times 12.089{,}4656 \text{ lb/jam ft}^2 \times 1{,}1042 \text{ ft} \times 54{,}3314}{5{,}22 \times 10^{10} \times 0{,}0725 \text{ ft} \times 0{,}96 \text{ ft} \times 1}$ ΔP_s= 0,0043 psi ΔP_s yang diizinkan=10 psi 0,0043 psi < 10 psi (Memenuhi)

9) *Cooler* 1 (CO-1091)

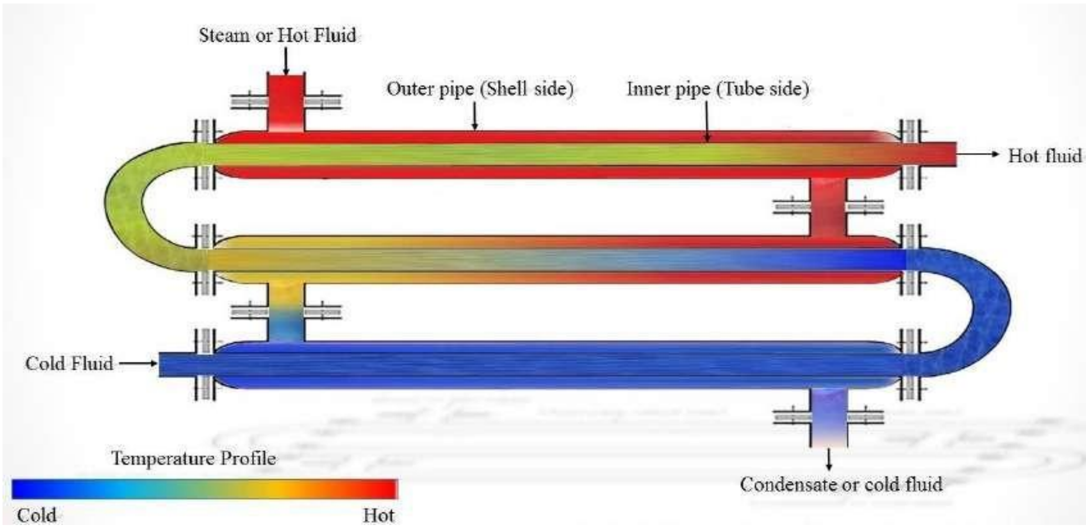
Fungsi : Untuk mendinginkan produk bawah hasil *deodorizer*

Tipe : *Double Pipe*

Bahan konstruksi : *Dupllex Stainless steel* Tipe-2205

Jumlah : 1 unit

Fasa : Cair



Gambar LC-10. *Cooler* 1

Data:

- Laju alir *hot fluid* (*bottom product*): 1.279,6562 kg/jam : 2.821,1301 lb/jam
- Laju alir *cold fluid* (*cooling water*): 15.310,3459 kg/jam : 33.753,1886 lb/jam
- Q : 153.103,4592 kkal/jam : 607.514,5261 btu/jam
- Tekanan : 1 atm
- T_1 : 329,23 °C : 624,614 °F
- T_2 : 30 °C : 86 °F
- t_1 : 28 °C : 82,4 °F
- t_2 : 38 °C : 100,4 °F

1. Menentukan Jenis *Cooler*

a. Menghitung LMTD

Hot fluid		*Cold Fluid*	*Difference*	
624,614	***High Temperatur***	100,4	524,214	**Δt_2**
86	***Low Temperatur***	82,4	3,6	**Δt_1**
			520,614	**$\Delta t_2 - \Delta t_1$**

$$LMTD = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln\left(\frac{T_1 - t_2}{T_2 - t_1}\right)}$$ DQ Kern, Pers 6.17 hal 117

$$LMTD = \frac{(624{,}614\ °F - 100{,}4\ °F) - (86\ °F - 82{,}4\ °F)}{\ln\left(\frac{624{,}614\ °F - 100{,}4\ °F}{86\ °F - 82{,}4\ °F}\right)}$$

$$= 104{,}52\ °F$$

b. Luas Area Perpindahan Panas

Diketahui viskositas *hot fluid* : 8,2309 cP

Berdasarkan *Table 8 - DQ Kern Page 840,* diperoleh :

Coolers

Hot fluid	Cold fluid	Overall U_D
Water	Water	250–500§
Methanol	Water	250–500§
Ammonia	Water	250–500§
Aqueous solutions	Water	250–500§
Light organics*	Water	75–150
Medium organics†	Water	50–125
Heavy organics‡	Water	5–75‖
Gases	Water	2–50¶
Water	Brine	100–200
Light organics	Brine	40–100

Maka dipilih U_d = 40 Btu/jam ft^2 °F

Maka,

$$A = \frac{Q}{U_d \times LMTD}$$ DQ. Kern Pers 7.42 Hal 144

$$A = \frac{607.514,5261 \text{ btu/jam}}{40 \text{ Btu/jam ft}^2\ °F \times 104,52\ °F}$$

$A = 145,3106\ ft^2$

Karena nilai A < 200 ft^2 maka tipe *heat exchanger* yang digunakan adalah *double pipe* (*DQ Kern Page 103*)

2. Pemilihan Ukuran *Double Pipe*

Berdasarkan *Table 6.2 DQ. Kern Page 110* maka dipilih ukuran *double pipe* berikut ini.

	Outer pipe	***Inner Pipe***	**Satuan**
IPS	3	2	In
Sch	40	40	
OD	3,5	2,38	In
ID	3,068	2,067	In
a''	0,917	0,622	ft^2/ft

3. Menentukan *caloric temperature*

$T_{av} = \frac{T_1 + T_2}{2}$ DQ.Kern Hal 113

$T_{av} = \frac{624,614\ °F + 86\ °F}{2}$

$= 355,307\ °F$

$t_{av} = \frac{t_1 + t_2}{2}$ DQ.Kern Hal 113

$t_{av} = \frac{82,4\ °F + 100,4\ °F}{2}$

$= 91\ °F$

Annulus (Top product)	*Inner Pipe (Cooling Water)*
4. *Flow area* $a_a = \frac{\pi(D_2^2 - D_1^2)}{4}$ DQ. Kern Pers 6.3 $a_a = \frac{3,14\ ((0,2557\ ft)^2 - (0,1983\ ft)^2)}{4}$ $= 0,0205\ ft^2$ *Equivalent diameter* $D_e = \frac{(D_2^2 - D_1^2)}{D_1}$ DQ. Kern Hal 111 $D_e = \frac{(0,2557\ ft)^2 - (0,1983\ ft)^2}{0,1983\ ft}$ $= 0,1314\ ft$	4. *Flow area* $a_p = \frac{\pi(D^2)}{4}$ DQ. Kern Hal 111 $a_p = \frac{3,14\ ((0,1723\ ft)^2)}{4}$ $= 0,1753\ ft^2$
5. Laju alir massa $G_a = \frac{W}{a_a}$ DQ. Kern Hal 114 $G_a = \frac{2.821,1301\ lb/jam}{0,0205\ ft^2}$ $= 137.616,1024\ lb/jam\ ft^2$	5. Laju alir massa $G_p = \frac{W}{a_p}$ DQ. Kern Hal 114 $G_p = \frac{33.753,1886\ lb/jam}{0,1353\ ft^2}$ $= 249.469,2432\ lb/jam\ ft^2$
6. Bilangan Reynold T_{av} = 355,307 °F μ *top product* = 1,3 cP = 3,1450 lb/ft jam DQ. Kern Hal 825	6. Bilangan Reynold T_{av} = 91 °F μ *Cooling water* = 0,8 cP = 1,9354 lb/ft jam DQ. Kern Hal 823

	Sp gr at 300°F	X	Y
Lauric	0.792	10.1	23.1
Oleic	0.799	10.0	25.2
Palmitic	0.786	9.2	25.9
Stearic	0.789	10.5	25.5

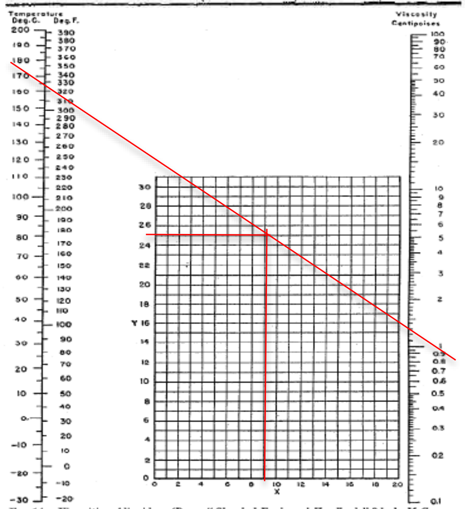


FIG. 14. Viscosities of liquids. (Perry, "Chemical Engineers' Handbook," 3d ed., McGraw

$$R_{ea} = \left(\frac{D_e \times G_a}{\mu}\right) \quad \text{DQ. Kern Hal 114}$$

$$R_{ea} = \left(\frac{0{,}1314 \text{ ft} \times 137.616{,}1024 \text{ lb/jam ft}^2}{3{,}1450 \text{ lb/ft jam}}\right)$$

$$= 5.749{,}6839$$

7. jH

jH = 22 DQ. Kern Hal 834

	X	Y		X	Y
Ethyl chloride	14.8	6.0	Toluene	13.7	10.4
Ethyl ether	14.5	5.3	Trichloroethylene	14.8	10.5
Ethyl formate	14.2	8.4	Turpentine	11.5	14.9
Ethyl iodide	14.7	10.3	Vinyl acetate	14.0	8.8
Ethylene glycol	6.0	23.6	Water	10.2	13.0
Formic acid	10.7	15.8	Xylene, ortho	13.5	12.1
Freon-11	14.4	9.0	Xylene, meta	13.9	10.6
Freon-12	16.8	5.6	Xylene, para	13.9	10.9

* From Perry, J. H., "Chemical Engineers' Handbook," 3d ed., McGraw-Hill Book Company, Inc.,

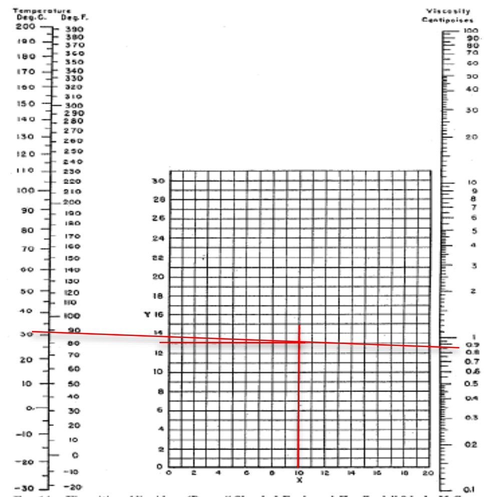


FIG. 14. Viscosities of liquids. (Perry, "Chemical Engineers' Handbook," 3d ed., McGraw

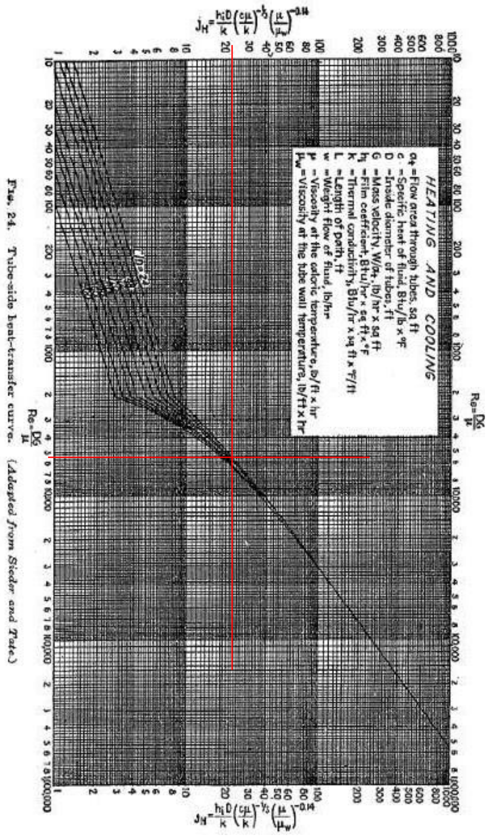
$$R_{ep} = \left(\frac{D \times G_p}{\mu}\right) \quad \text{DQ. Kern Hal 114}$$

$$R_{ep} = \left(\frac{0{,}1723 \text{ ft} \times 249.469{,}2432 \text{ lb/jam ft}^2}{1{,}9354 \text{ lb/ft jam}}\right)$$

$$= 53.729{,}4383$$

7. jH

jH = 150 DQ. Kern Hal 834



8. Konduktivitas dan kapasitas panas

Pada t_{av}= 355,307 °F

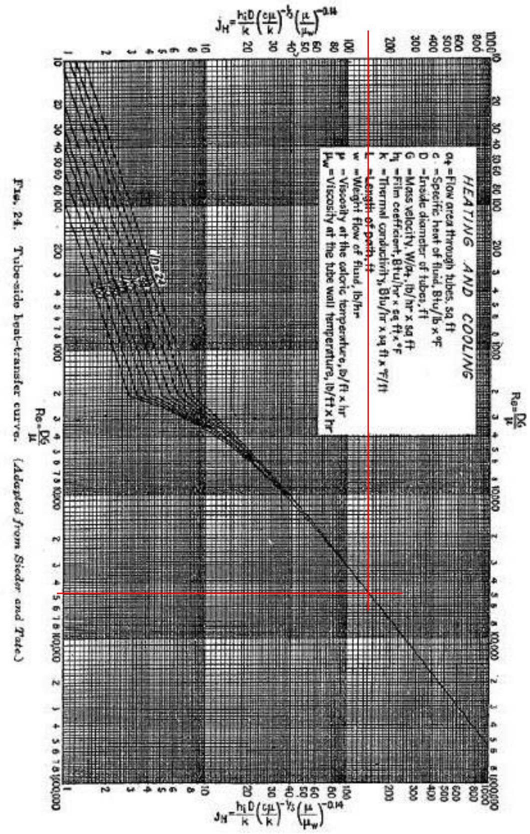
c = 0,121 btu/lb °F

k = 0,0835 btu/(hr)(ft^2)(°F)

DQ. Kern Hal 800

$$\left(\frac{c\,\mu}{k}\right)^{1/3} = \left(\frac{0{,}121\,\frac{\text{btu}}{\text{lb °F}} \times 3{,}1450\,\frac{\text{lb}}{\text{hr ft}}}{0{,}0835\,\frac{\text{Btu}}{(\text{hr})(\text{ft}^2)(\text{°F/ft})}}\right)^{\frac{1}{3}}$$

= 1,6580 ft



8. Konduktivitas dan kapasitas panas

Pada t_{av}= 91 °F

c = 0,1 btu/lb °F

k = 0,3560 btu/(hr)(ft^2)(°F)

DQ. Kern Hal 800

$$\left(\frac{c\,\mu}{k}\right)^{1/3} = \left(\frac{0{,}1\,\frac{\text{btu}}{\text{lb °F}} \times 1{,}9354\,\frac{\text{lb}}{\text{hr ft}}}{0{,}3560\,\frac{\text{Btu}}{(\text{hr})(\text{ft}^2)(\text{°F/ft})}}\right)^{\frac{1}{3}}$$

= 0,8162 ft

9. h_o	9. h_i
$h_o = jH \frac{k}{D} (\frac{c\,\mu}{k})^{\frac{1}{3}} (\frac{\mu}{\mu_w})^{0,14}$ pers 6.15a DQ Kern	$h_i = jH \frac{k}{D} (\frac{c\,\mu}{k})^{\frac{1}{3}} (\frac{\mu}{\mu_w})^{0,14}$ pers 6.15a DQ Kern
$h_o = (22) \frac{0,0835 \frac{btu}{(hr)\,(ft^2)(°F/ft)}}{0,1314\ ft} (1,6580\ ft)(1)$	$h_i = (150) \frac{0,3560 \frac{btu}{(hr)\,(ft^2)(°F/ft)}}{0,1723\ ft} (0,8162\ ft)(1)$
= 23,1792 btu/(hr)(ft^2)(°F)	= 252,9604 btu/(hr)(ft^2)(°F)
10. Koreksi h_i	10. Koreksi h_i
$h_{io} = h_i \frac{ID}{OD}$ pers 6.15 DQ Kern	$h_{io} = h_i \frac{ID}{OD}$ pers 6.15 DQ Kern
$h_{io} = 138.2850 \frac{btu}{(hr)\,(ft^2)(°F)} \frac{0,1723\ ft}{0,1983\ ft}$	$h_{io} = 252,9604 \frac{btu}{(hr)\,(ft^2)(°F)} \frac{0,1723\ ft}{0,1983\ ft}$
= 120,0988 btu/(hr)(ft^2)(°F)	= 219,6929 btu/(hr)(ft^2)(°F)
Temperatur Dinding	Temperatur Dinding
$t_w = t_{avg} + \frac{h_o}{h_{io} + h_o} \times (T_{avg} - t_{avg})$	$t_w = t_{avg} + \frac{h_o}{h_{io} + h_o} \times (T_{avg} - t_{avg})$
$t_w = 91\ °F + \frac{23,1792\ btu/hr\ ft^2\ °F}{(120,0988+23,1792)\ btu/(hr)(ft^2)(°F)} \times (355-91)°F$	$t_w = 91\ °F + \frac{23,1792\ btu/hr\ ft^2\ °F}{(120,0988+23,1792)\ btu/(hr)(ft^2)(°F)} \times (355-91)°F$
= 134 °F	= 134 °F
Pada t_w = 134 °F	Pada t_w = 134 °F
μ = 2 lb/ft jam	μ = 1,5 lb/ft jam
Maka,	Maka,
$\phi_p = (\frac{\mu}{\mu_w})^{0,14}$	$\phi_p = (\frac{\mu}{\mu_w})^{0,14}$
$\phi_p = (\frac{3,1450\ lb/ft\ jam}{2\ lb/ft\ jam})^{0,14}$	$\phi_p = (\frac{1,9354\ lb/ft\ jam}{1,5\ lb/ft\ jam})^{0,14}$
= 1,0654	= 1,0363
h_o sebenarnya = 23,1792 btu/(hr)(ft^2)(°F) × 1,0654	h_{io} sebenarnya = 219,6929 btu/(hr)(ft^2)(°F) × 1,0363
= 24,6951 btu/(hr)(ft^2)(°F)	= 227,6678 btu/(hr)(ft^2)(°F)

11. Clean overall coefficient

$$U_c = \frac{h_{io} \times h_o}{h_{io} + h_o} \quad \text{Pers 6.7 DQ Kern}$$

$$U_c = \frac{227{,}6678 \frac{btu}{hr\ ft^2 °F} \times 24{,}6951 \frac{btu}{hr\ ft^2 °F}}{227{,}6678 \frac{btu}{hr\ ft^2 °F} + 24{,}6951 \frac{btu}{hr\ ft^2 °F}} = 22{,}2785 \frac{btu}{hr\ ft^2 °F}$$

12. Design overall coefficient

$$\frac{1}{U_d} = \frac{1}{U_c} + R_d \quad \text{Pers 6.10 DQ Kern}$$

$$\frac{1}{U_d} = \frac{1}{22{,}2785 \frac{btu}{hr\ ft^2 °F}} + 0{,}001\ ft^2\ hr\ °F/btu$$

$$U_d = 21{,}7865 \frac{btu}{hr\ ft^2 °F}$$

13. Surface area required

$$A = \frac{Q}{U_d \times LMTD} \quad \text{DQ. Kern Pers 7.42 Hal 144}$$

$$A = \frac{607.514{,}5261\ btu/jam}{21{,}7865\ btu/jam\ ft^2\ °F \times 104{,}52°F}$$

$$A = 266{,}7902\ ft^2$$

14. Menghitung jumlah *hairpin*

$$\textit{Required length} = \frac{A}{a''}$$

$$\textit{Required length} = \frac{266{,}7902\ ft^2}{0{,}622\ ft^2/ft}$$

Required length = 428,9232 ft

Digunakan Panjang pipa untuk *double pipe heat exchanger* : 40 ft

1 *hairpin* terdiri dari 2 pipa, maka jumlah *hairpin* yang diperlukan adalah :

$$Hairpin = \frac{L}{2 \times L_H}$$

$$Hairpin = \frac{428{,}9232 \text{ ft}}{2 \times 40 \text{ ft}}$$

Hairpin = 5,3615

≈ 6

Koreksi Panjang pipa

L koreksi = 2 × L *Hairpin* × Banyak *Hairpin*

L koreksi = 2 × 40 ft × 6

L koreksi = 480 ft

15. *Actual design overall coefficient*

actual surface = *required length* × a"

actual surface = 480 ft × 0,622 ft^2/ft = 298,56 ft^2

$$U_d \; actual = \frac{Q}{A \times LMTD}$$

$$U_d actual = \frac{607.514{,}5261 \text{ btu/jam}}{298{,}56 \text{ ft}^2 \times 104{,}52 \text{ °F}}$$

U_d *actual* = 19,4682 btu/jam ft^2 °F

Asumsi benar karena U_d *actual* < U_d desain

R_d sebenarnya

$$R_d = \frac{U_c - U_d}{U_c \times U_d}$$

$$R_d = \frac{22{,}2785 \text{ btu/jam ft}^2 \text{ °F} - 19{,}4682 \text{ btu/jam ft}^2 \text{ °F}}{22{,}2785 \text{ btu/jam ft}^2 \text{ °F} \times 19{,}4682 \text{ btu/jam ft}^2 \text{ °F}}$$

R_d = 0,0065 ft^2 jam °F/btu

R_d yang diperlukan = 0,001 ft^2 jam °F/btu

R_d sebenarnya > R_d yang diperlukan (memenuhi)

16. Pressure drop

Annulus (Steam)	***Inner Pipe (PFAD)***
1. $D_e' = D_2 - D_1$ Pers 6.4 DQ Kern $D_e' = 0{,}2557\ ft - 0{,}1983\ ft$ $D_e' = 0{,}0574\ ft$ $Re_a' = \frac{D_e' \times G_a}{\mu}$ $Re_a' = \frac{0{,}0574\ ft \times 137.616{,}1024\ lb/hr\ ft^2}{3{,}1450\ lb/ft\ hr}$ $Re_a' = 2.511{,}6580$ (turbulen) $f = 0{,}0035 + \frac{0{,}264}{(DG/\mu)^{0{,}42}}$ Pers 3.47b DQ Kern $f = 0{,}0035 + \frac{0{,}264}{(2.511{,}6580)^{0{,}42}}$ $f = 0{,}0134$ 2. $\Delta F_a = \frac{4 \times f \times Ga^2 \times L}{2 \times g \times \rho^2 \times D_e}$ Pers 6.14 DQ Kern $g = 4{,}18 \times 10^8 ft/hr^2$ $\rho = 38{,}4046\ lb/ft^3$ $\Delta F_a = \frac{4 \times 0{,}0134 \times (137.616{,}1024\ lb/hr\ ft)^2 \times 480\ ft}{2 \times 4{,}18 \times 10^8 ft/hr \times (38{,}4046\ lb/ft^3)^2 \times 0{,}0574\ ft}$ $\Delta F_a = 3{,}4425\ ft$ 3. $V = \frac{G}{3600\rho}$ $V = \frac{137.616{,}1024\ lb/hr\ ft^2}{3600 \times 38{,}4046\ lb/ft^3}$ $V = 0{,}9954\ ft/s$ $\Delta F_l = \frac{V^2}{2g}$	1. $Re_p = 53.729{,}4383$ (turbulen) *Fanning factor* untuk turbulen : $f = 0{,}0035 + \frac{0{,}264}{(DG/\mu)^{0{,}42}}$ Pers 3.47b DQ Kern $f = 0{,}0035 + \frac{0{,}264}{(53.729{,}4383)^{0{,}42}}$ $f = 0{,}0062$ 2. $\Delta F_p = \frac{4 \times f \times Gp^2 \times L}{2 \times g \times \rho^2 \times D_e}$ Pers 6.14 DQ Kern $g = 4{,}18 \times 10^8 ft/hr^2$ $\rho = 62{,}4300\ lb/ft^3$ $\Delta F_p = \frac{4 \times 0{,}0062 \times (249.469{,}2432\ lb/hr\ ft)^2 \times 480\ ft}{2 \times 4{,}18 \times 10^8 ft/hr \times (62{,}4300\ lb/ft^3)^2 \times 0{,}1723\ ft}$ $\Delta F_p = 1{,}3196\ ft$ 3. $\Delta P_p = \frac{(\Delta F_p)\rho}{144}$ Pers 3.45 DQ Kern $\Delta P_p = \frac{(1{,}3196\ ft)\ 62{,}4300\ lb/ft^3}{144}$ $\Delta P_a = 0{,}5721$ psi ΔP_a yang diizinkan=10 psi 0,5721 psi < 10 psi (Memenuhi)

$\Delta F_l = \dfrac{(0{,}9954\ ft/s)^2}{2 \times 32{,}2\ ft/s^2}$ ΔF_l = 0,0154 ft 4. $\Delta P_a = \dfrac{(\Delta Fa + \Delta F1)\rho}{144}$ Pers 3.45 DQ Kern $\Delta P_a = \dfrac{(3{,}4425\ ft + 0{,}0154\ ft)\ 38{,}4046\ lb/ft^3}{144}$ ΔP_a= 0,9222 psi ΔP_a yang diizinkan=10 psi 0,9222 psi < 10 psi (Memenuhi)	

10) *Storage Tank Potassium Hydroxide* (ST-1102)

Fungsi : Tempat menyimpan Kalium hidroksida padat

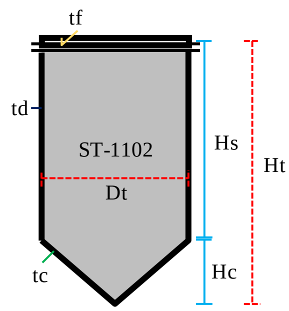
Tipe : Silinder vertikal dengan alas *conical* dan tutup datar

Bahan konstruksi : *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*

Jumlah : 1 unit

Sifat bahan : Volatil, higroskopis dan korosif

Fasa : Padat



Gambar LC-11. *Storage Tank* KOH

Data:

- Laju alir umpan : 263,8290 kg/jam : 581,6374 lb/jam
- Densitas campuran : 2.126,2 kg/m^3 : 132,7387 lb/ft^3
- Tekanan : 1 atm
- Viskositas Campuran : 24,238 cP : 0,0163 lb/ft.s
- Lama Penyimpanan : 3 Hari : 72 jam

1. Kapasitas Tangki

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

$$V_p = \frac{263{,}8290 \text{ kg/jam} \times 72 \text{ jam}}{2.126{,}2 \text{ kg/m}^3}$$

$$V_p = 8{,}9341 \text{ m}^3$$

$$= 315{,}4988 \text{ ft}^3$$

$$= 545.192{,}2313 \text{ in}^3$$

$$= 2.360{,}1391 \text{ gal}$$

Dengan Mempertimbangkan faktor keamanan 10 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$$V_p = 0{,}9\ V_t$$

$$V_t = \frac{V_p}{0{,}9}$$

$$V_t = \frac{8{,}9341 \text{ m}^3}{0{,}9}$$

$$V_t = 9{,}9268 \text{ m}^3$$

$$= 350{,}5550 \text{ ft}^3$$

$$= 605.770{,}5019 \text{ in}^3$$

$$= 2.622{,}3826 \text{ gal}$$

2. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1,1775\ D_t^3$

b. Volume *Conical*

$V_c = \frac{\pi}{6} \times D_t^2 \times H_c$ Dengan $H_c = 1/2\ D_t \tan 45°$ (*Table 18.4, Chemical Process Equipment*, S. Walas, Page 658)

$V_c = 0,2617\ D_t^3$

c. Diameter Tangki

$V_t = V_s + V_c$

$V_t = 1,1775\ D_t^3 + 0,2617\ D_t^3$

$V_t = 1,4392\ D_t^3$

$D_t^3 = \frac{V_t}{1,4392}$

$D_t^3 = \frac{9.9268\ m^3}{1,4392}$

$D_t = \sqrt[3]{\frac{9.9268\ m^3}{1,4392}}$

$D_t = 1,9023$ m

= 6,2395 ft

= 74,8936 in

d. Tinggi Silinder

$H_s = 1,5\ D_t$

H_s = 1,5 × 1,9023 m

H_s = 2,8535 m

= 99,3595 ft

= 112,3423 in

e. Tinggi *Conical*

H_c = 1/2 D_t tan 45°

H_c = 1/2 × 1,9023 m × 1

H_c = 0,9512 m

= 3,1199 ft

= 37,4487 in

f. Tinggi Tangki

H_t = H_s + H_c

H_t = 2,8535 m + 0,9512 m

H_t = 3,8047 m

P_d = 14,7 psi

R = 37,4468 in

S = 18700 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

g. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0{,}6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{14{,}7 \text{ psi} \times 37{,}4468 \text{ in}}{18700 \text{ psi} \times 0{,}85 - 0{,}6 \times 14{,}7 \text{ psi}} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2347 in

= 0,0060 m

= 0,0197 ft

= 5,9614 mm

h. Tebal Dinding *Conical*

$t_c = \frac{PD}{2(SE - 0{,}2P)\cos 30°} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_c = \frac{14{,}7 \text{ psi} \times 74{,}8936 \text{ in}}{2(18700 \text{ psi} \times 0{,}85 - 0{,}2 \times 14{,}7 \text{ psi})0{,}71} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_c = 0,2488 in

= 0,0063 m

= 0,0207 ft

= 6,3195 mm

i. Tebal Tutup Tangki

$t_f = D\sqrt{\frac{0{,}3\ P}{S}} + C$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$$t_f = 74,8936 \text{ in}\sqrt{\frac{0,3 \times 14,7 \text{ psi}}{18700 \text{ psi}}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun} = 0,5618 \text{ in}$$

= 1,3501 m

= 0,0343 ft

= 34,2925 mm

11) *Continous Flow Conveyor* (CFC-1101)

Fungsi : Mentransportasikan Kalium hidroksida padat ke *mixing tank* 1

Tipe : *Apron conveyor with pan*

Bahan konstruksi : *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*

Jumlah : 2 unit

Sifat bahan : Volatil, higroskopis dan korosif

Fasa : Padat

Gambar LC-12. *Continous Flow Conveyor*

Data:

- Laju alir umpan : 263,8290 kg/jam : 0,2391 ton/jam

- Densitas campuran : 2.126,2 kg/m^3 : 132,7387 lb/ft^3
- Tekanan : 1 atm
- Viskositas Campuran : 24,238 cP : 0,0163 lb/ft.s
- Faktor Keamanan : 10%

1. Kapasitas Conveyor

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

$$W = \frac{0,2391 \text{ ton/jam}}{0,9} = 0,3257 \text{ ton/jam}$$

2. Ukuran Conveyor

Dengan kapasitas di atas, dipilih *continuos flow conveyor* dengan spesifikasi sebagai berikut (Perry's 7th Ed, Tabel 21-11 Hal 21-19).

Lebar Conveyor	: 18 in	: 1,5 ft
Panjang Conveyor	: 13 m	: 42,64 ft
Kecepatan (u)	: 10 ft/min	: 3,0488 m/min
Lebar *Pan*	: 18 in	: 1,5 ft

3. Daya Conveyor

$$HP = 0,001\ [(\frac{L1}{30} + 5)\ u + (\frac{L2}{16} + 2L3)\ T]$$ Walas - Chemical Process Equipment, Pers 5.26

u : kecepatan = 10 ft/menit

T : kapasitas conveyor = 0,3257 ton/jam

L_1 : panjang total conveyor = 42,64 ft

Asumsi :

L_2 : jarak horizontal yang ditempuh = 10 m = 32,8 ft

L_3 : jarak vertikal yang ditempuh = 2,9 m = 9,84 ft

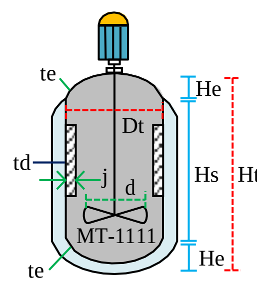
$$HP = 0{,}001\ \left[\left(\frac{L1}{30} + 5\right) u + \left(\frac{L2}{16} + 2L3\right) T\right]$$

$$HP = 0{,}001\ \left[\left(\frac{42{,}64\ ft}{30} + 5\right) 10\ ft/min + \left(\frac{32{,}8}{16} + 2 \times 9{,}84\ ft\right) 0{,}3257\ ton/jam\ \right]$$

$$HP = 0{,}0713 \approx 0{,}5$$

12) *Mixing Tank* 1 (MT-1111)

Fungsi	: Tempat melarutkan KOH padat menjadi larutan KOH 25%
Tipe	: Silinder vertikal dengan alas dan tutup *elipsoidal*
Bahan konstruksi	: *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*
Jumlah	: 1 unit
Sifat bahan	: Tidak volatil, korosif dan tidak higroskopis
Fasa	: Cair



Gambar LC-13. *Mixing Tank* 1

Data:

- Laju alir umpan : 1.034,209 kg/jam : 2.280,0172 lb/jam
- Densitas campuran : 1.287,2930 kg/m^3 : 80,3657 lb/ft^3
- Tekanan : 1 atm
- Viskositas Campuran : 0,894 cP : 0,0088 lb/ft.s
- Waktu Pelarutan : 60 menit : 1 jam

1. Kapasitas Tangki

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

$$V_p = \frac{1.034,209 \text{ kg/jam} \times 1 \text{ jam}}{1.287,2930 \text{ kg/m}^3}$$

V_p = 0,8034 m^3

= 28,3713 ft^3

= 49,026,4759 in^3

= 212,2358 gal

Dengan Mempertimbangkan faktor keamanan 20 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

V_p = 0,8 V_t

$$V_t = \frac{V_p}{0,8}$$

$$V_t = \frac{0,8034 \text{ m}^3}{0,8}$$

V_t = 1,0043 m^3

= 35.4659 ft^3

= 61.286,1461 in^3

= 265,3079 gal

2. Dimensi Tangki

a. Volume Silinder

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

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

V_s = 1,1775 D_t^3

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0{,}1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + 2\ V_e$

$V_t = 1{,}1775\ D_t^3 + 2\ (0{,}1308\ D_t^3)$

$V_t = 1{,}4391\ D_t^3$

$D_t^3 = \frac{V_t}{1{,}4391}$

$D_t^3 = \frac{1{,}0043\ m^3}{1{,}4391}$

$D_t = \sqrt[3]{\frac{1{,}0043\ m^3}{1{,}4391}}$

$D_t = 0{,}8870$ m

= 2,9094 ft

= 34,9212 in

d. Tinggi Silinder

$H_s = 1{,}5\ D_t$

$H_s = 1{,}5 \times 0{,}8870$ m

$H_s = 1{,}3305$ m

= 4,3640 ft

= 52,3818 in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 0{,}8870$ m

$H_e = 0{,}2218$ m

$= 0{,}7275$ ft

$= 8{,}7323$ in

f. Tinggi Tangki

$H_t = H_s + (2\ H_e)$

$H_t = 1{,}3305\ \text{m} + (2 \times 0{,}2218\ \text{m})$

$H_t = 1{,}7741$ m

g. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s + (2\ H_e))}{V_t}$$

$$H_c = \frac{0{,}8034\ \text{m}^3 \times (1{,}3305\ \text{m} + (2 \times 0{,}2218\ \text{m}))}{1{,}0043\ \text{m}^3}$$

$H_c = 1{,}4192$ m

$= 4{,}6550$ ft

$= 55{,}8739$ in

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

$P_c = 1.287{,}2930\ \text{kg/m}^3 \times 9{,}81\ \text{m/s}^2 \times 1{,}4192\ \text{m}$

$P_c = 17.922{,}1463\ \text{kg.m/s}^2$

$= 0{,}1738$ atm

$= 2{,}5541$ psi

i. Tekanan Desain

$P_d = P_{op} + P_c$

P_d = 1 atm + 0,1738 atm

P_d = 1,1738 atm

= 17,2549 psi

P_d = 17,2549 psi

R = 17,4606 in

S = 18700 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{17,2549 \text{ psi} \times 17,4606 \text{ in}}{18700 \text{ psi} \times 0,85 - 0,6 \times 17,2549 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2190 in

= 0,0056 m

= 0,0184 ft

= 5,5626 mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0,2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{17,2549 \text{ psi} \times 34,9212 \text{ in}}{2 \times 18700 \text{ psi} \times 0,85 - 0,2 \times 17,2549 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2190 in

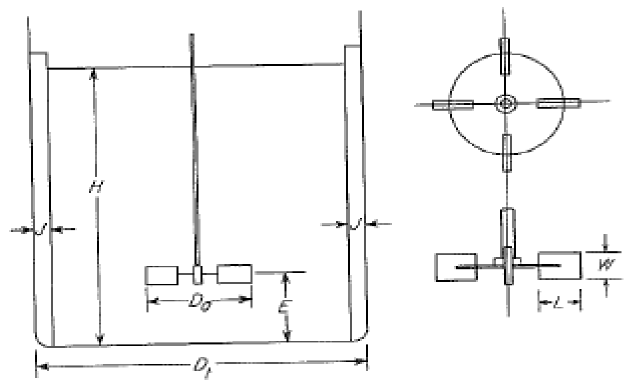
= 0,0056 m

= 0,0184 ft

= 5,5626 mm

3. Desain Pengaduk

Viskositas umpan < 4000 cP, maka dipilih *propeller* berdaun tiga (Kecepatan 1800 rpm) (*Walas - Selection Design & Chemical Process Equipment ed 1st, Page 288*).



Gambar LC-14. Desain Pengaduk *Mixing Tank* 1

a. Diameter Pengaduk

$$d = \frac{D_t}{3}$$

$$d = \frac{0,8870 \text{ m}}{3}$$

d = 0,2957 m

= 0,9699 ft

b. Panjang Daun Pengaduk

$$L = \frac{d}{4}$$

$$L = \frac{0,2957\ m}{4}$$

L = 0,0739 m

= 0,2424 ft

c. Lebar Daun Pengaduk

$$W = \frac{d}{5}$$

$$W = \frac{0,2957\ m}{5}$$

W = 0,0591 m

= 0,1938 ft

d. Tinggi Pengaduk Dari Dasar Tangki

$$E = \frac{D_t}{3}$$

$$E = \frac{0,8870\ m}{3}$$

E = 0,2957 m

= 0,9699 ft

e. Lebar *Baffle*

$$J = \frac{D_t}{12}$$

$$J = \frac{0,8870\ m}{12}$$

J = 0,0739 m

= 0,2424 ft

f. Kecepatan Putar Pengaduk

Berdasarkan persamaan 6-18 *Robert Treyball-Mass Transfer Operation,* kecepatan putar pengaduk dapat dihitung dengan persamaan berikut.

Dengan $g_c = 32{,}2$ ft/s^2

σ = 72,75 dyn/cm (*Mc.cabe – Unit Operation Of Chemical Engineering 5th Page 274*).

= 0,0537 lb/ft

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

$$\frac{N_d}{\left(\frac{0{,}0537 \text{ lb/ft} \times 32{,}2 \text{ ft/s}^2}{80{,}3657 \text{ lb/ft}^3}\right)^{0,25}} = 1{,}22 + 1{,}25 \left(\frac{2{,}9094 \text{ ft}}{0{,}9699 \text{ ft}}\right)$$

$$N_d = 2{,}7123 \text{ rps}$$

g. Daya Pengadukan

Berdasarkan persamaan 9-17 *Mc.cabe – Unit Operation Of Chemical Engineering 5^t,* bilangan *reynold* dapat dihitung dengan persamaan berikut.

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

$$N_{Re} = \frac{80{,}3657 \text{ lb/ft}^3 \times 2{,}7123 \text{ rps} \times (0{,}9699 \text{ ft})^2}{0{,}0019 \text{ lb/ft.s}}$$

N_{Re} = 107.921,6989

Karena Nre > 10.000, maka berdasarkan persamaan 9.24 *Mc.cabe – Unit Operation Of Chemical Engineering 5^t,* daya pengadukan menggunakan dapat dihitung dengan persamaan berikut.

Dengan K_T = 0,87 (*Mc. Cabe & Smith - Unit Operations Of Chemical Engineering 5th, Page 254*)

$$P = \frac{K_T N^3 D_a^5 \rho}{g_c}$$

$$P = \frac{0{,}87 \times (2{,}7123\ rps)^3 \times (0{,}9699\ ft)^5 \times 80{,}3657\ lb/ft^3}{32{,}2\ ft/s^2}$$

P = 37,1862 ft.lbf/s

P = 0,0676 HP

h. Daya Motor

Efisiensi Motor = 80%

$$\text{Daya Motor} = \frac{0{,}0676\ HP}{80\%}$$

Daya Motor = 0,0845 HP

≈ 0,5 HP

13) *Heater* 2 (HE-1122)

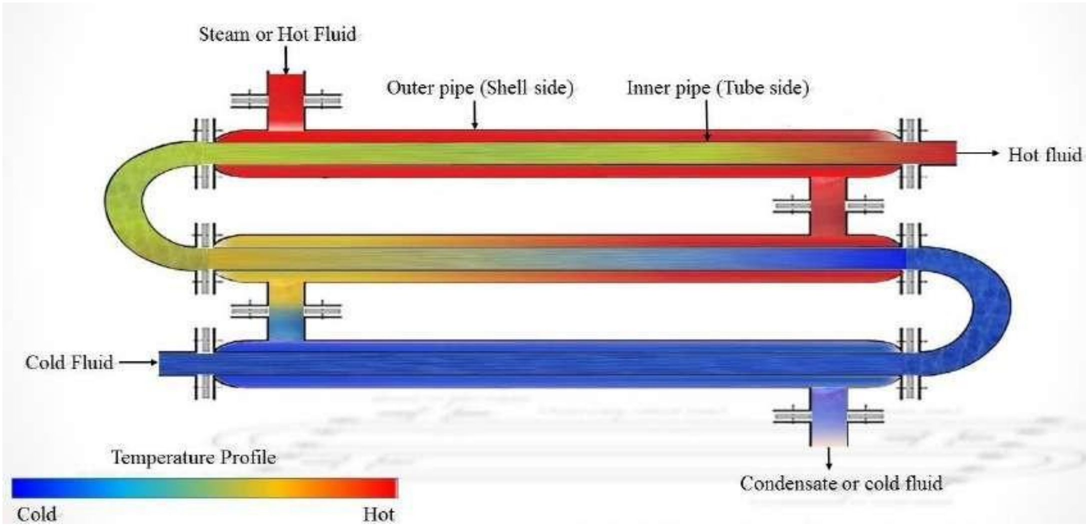
Fungsi : Untuk memanaskan larutan KOH sebelum masuk ke dalam *netralizer reactor*

Tipe : *Double Pipe*

Bahan konstruksi : *Dupllex Stainless steel* Tipe-2205

Jumlah : 1 unit

Fasa : Cair



Gambar LC-15. *Heater* 2

Data:

- Laju alir *hot fluid (Steam)* : 102,1552 kg/jam : 225,2114 lb/jam
- Laju alir *cold fluid* (KOH) : 1.034,2089 kg/jam : 2.280,0169 lb/jam
- Q : 42.824,1467 kkal/jam : 166.926,2141 btu/jam
- Tekanan : 1 atm
- T_1 : 242 ^oC : 467,6 ^oF
- T_2 : 242 ^oC : 467,6 ^oF
- t_1 : 30 ^oC : 86 ^oF
- t_2 : 80 ^oC : 176 ^oF

1. Menentukan Jenis *Heater*

a. Menghitung LMTD

Hot fluid		***Cold Fluid***	***Difference***	
467,6	***High Temperatur***	176	291,6	Δt_2
467,6	***Low Temperatur***	86	381,6	Δt_1
			90	Δt_2-Δt_1

$$\text{LMTD} = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln\left(\frac{T_1 - t_2}{T_2 - t_1}\right)}$$ DQ Kern, Pers 6.17 hal 117

$$\text{LMTD} = \frac{(467{,}6\ °F - 176\ °F) - (467{,}6\ °F - 86\ °F)}{\ln\left(\frac{467{,}6\ °F - 176\ °F}{467{,}6\ °F - 86\ °F}\right)}$$

$$= 334{,}5725\ °F$$

b. Luas Area Perpindahan Panas

Diketahui viskositas *cold fluid* : 2,9812 cP

Berdasarkan *Table 8 - DQ Kern Page 840,* diperoleh :

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¶

Maka dipilih U_d = 250 Btu/jam ft^2 °F

Maka,

$$A = \frac{Q}{U_d \times \text{LMTD}}$$ DQ. Kern Pers 7.42 Hal 144

$$A = \frac{166.926{,}2141\ \text{btu/jam}}{250\ \text{Btu/jam ft}^2\ °F \times 334{,}5725\ °F}$$

A = 2,0316 ft^2

Karena nilai A < 200 ft^2 maka tipe *heat exchanger* yang digunakan adalah *double pipe* (*DQ Kern Page 103*)

2. Pemilihan Ukuran *Double Pipe*

Berdasarkan *Table 6.2 DQ. Kern Page 110* maka dipilih ukuran *double pipe* berikut ini.

	Outer pipe	*Inner Pipe*	**Satuan**
IPS	3	2	In
Sch	40	40	
OD	3,5	2,38	In
ID	3,068	2,067	In
a''	0,917	0,622	ft^2/ft

3. Menentukan *caloric temperature*

$T_{av} = \frac{T_1 + T_2}{2}$ DQ.Kern Hal 113

$T_{av} = \frac{467,6\ °F + 467,6\ °F}{2}$

$= 467,6\ °F$

$t_{av} = \frac{t_1 + t_2}{2}$ DQ.Kern Hal 113

$t_{av} = \frac{176\ °F + 86\ °F}{2}$

$= 131\ °F$

Annulus (Steam)	*Inner Pipe (KOH)*
4. *Flow area* $a_a = \frac{\pi(D_2^2 - D_1^2)}{4}$ DQ. Kern Pers 6.3 $a_a = \frac{3,14\ ((0,2557\ ft)^2 - (0,1983\ ft)^2)}{4}$ $= 0,0205\ ft^2$ *Equivalent diameter* $D_e = \frac{(D_2^2 - D_1^2)}{D_1}$ DQ. Kern Hal 111 $D_e = \frac{(0,2557\ ft)^2 - (0,1983\ ft)^2}{0,1983\ ft}$ $= 0,1314\ ft$	4. *Flow area* $a_p = \frac{\pi(D^2)}{4}$ DQ. Kern Hal 111 $a_p = \frac{3,14\ ((0,1723\ ft)^2)}{4}$ $= 0,1753\ ft^2$
5. Laju alir massa $G_a = \frac{W}{a_a}$ DQ. Kern Hal 114	5. Laju alir massa $G_p = \frac{W}{a_p}$ DQ. Kern Hal 114

$$G_a = \frac{225{,}2114 \text{ lb/jam}}{0{,}0205 \text{ ft}^2}$$

$= 10.985{,}9220$ lb/jam ft^2

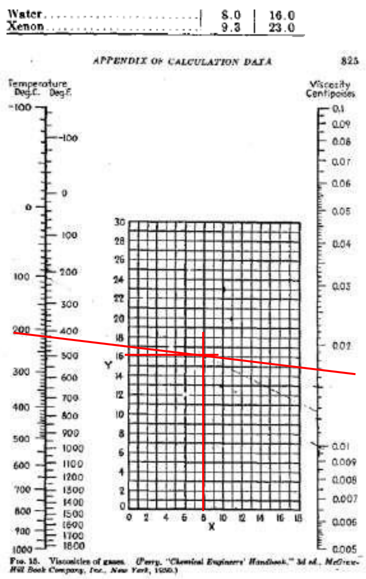
6. Bilangan Reynold

$T_{av} = 467{,}6$ °F

μ *steam* = 0,017 cP

= 0,0411 lb/ft jam

DQ. Kern Hal 825



$$R_{ea} = \left(\frac{D_e \times G_a}{\mu}\right) \quad \text{DQ. Kern Hal 114}$$

$$R_{ea} = \left(\frac{0{,}1314 \text{ ft} \times 10.985{,}9220 \text{ lb/jam ft}^2}{0{,}0411 \text{ lb/ft jam}}\right)$$

$= 35.122{,}8747$

$$G_p = \frac{2.280{,}0169 \text{ lb/jam}}{0{,}1353 \text{ ft}^2}$$

$= 16.851{,}5661$ lb/jam ft^2

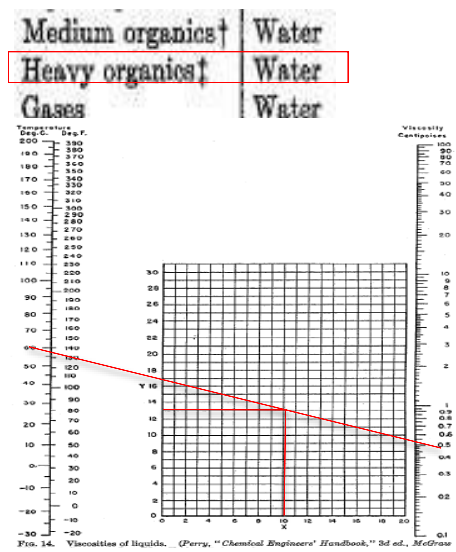
6. Bilangan Reynold

$T_{av} = 131$ °F

μ KOH = 0,2 cP

= 0,4838 lb/ft jam

DQ. Kern Hal 823



$$R_{ep} = \left(\frac{D \times G_p}{\mu}\right) \quad \text{DQ. Kern Hal 114}$$

$$R_{ep} = \left(\frac{0{,}1723 \text{ ft} \times 16.851{,}5661 \text{ lb/jam ft}^2}{0{,}4838 \text{ lb/ft jam}}\right)$$

$= 14.517{,}6242$

7. h_o

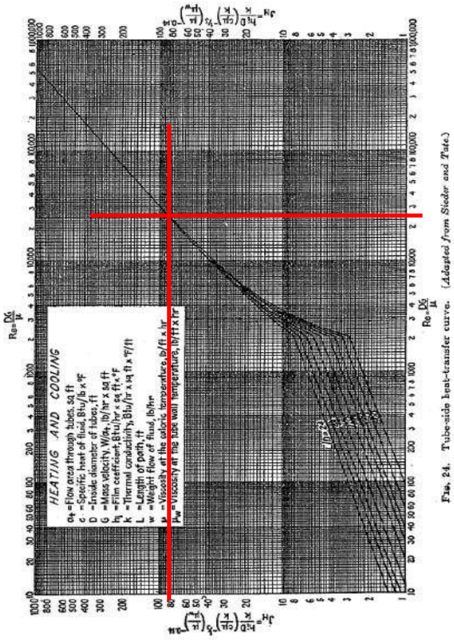
Steam yang mengalami perubahan fasa tanpa perubahan suhu maka $h_i = h_o = h_{io}$

(DQ. Kern Hal 163-164)

Maka, h_o = 1500 btu/hr ft^2 °F

7. jH

jH = 85 DQ. Kern Hal 834



8. Konduktivitas dan kapasitas panas

Pada t_{av}= 131 °F

c = 0,42 btu/lb °F

k = 0,3768 btu/(hr)(ft^2)(°F)

DQ. Kern Hal 800

$$\left(\frac{c\,\mu}{k}\right)^{1/3} = \left(\frac{0{,}42\,\frac{btu}{lb\ °F} \times 0{,}4838\,\frac{Ib}{hr\ ft}}{0{,}3768\,\frac{Btu}{(hr)\ (ft^2)(°F/ft)}}\right)^{\frac{1}{3}}$$

= 0,8140 ft

9. h_i

$$h_i = jH\frac{k}{D}\left(\frac{c\,\mu}{k}\right)^{\frac{1}{3}}\left(\frac{\mu}{\mu_w}\right)^{0,14}$$ pers 6.15a DQ Kern

	$h_i = (85) \dfrac{0,3768 \dfrac{btu}{(hr)\,(ft^2)(°F/ft)}}{0,1723\ ft} (0,8140\ ft)(1)$ $= 151,3105\ btu/(hr)(ft^2)(°F)$ 10. Koreksi h_i $h_{io} = h_i \dfrac{ID}{OD}$ pers 6.15 DQ Kern $h_{io} = 151,3105 \dfrac{btu}{(hr)\,(ft^2)(°F)} \dfrac{0,1723\ ft}{0,1983\ ft}$ $= 131,4715\ btu/(hr)(ft^2)(°F)$ Temperatur Dinding $t_w = t_{avg} + \dfrac{h_o}{h_{io}+h_o} \times (T_{avg} - t_{avg})$ $t_w = 131\ °F + \dfrac{1500\ btu/hr\ ft^2\ °F}{(131,4715 + 1500)\ btu/(hr)(ft^2)(°F)} \times (467,6 - 131)°F$ $= 458,4358\ °F$ Pada $t_w = 458,4358\ °F$ $\mu = 0,001$ lb/ft jam Maka, $\phi_p = (\dfrac{\mu}{\mu_w})^{0,14}$ $\phi_p = (\dfrac{0,4838\ lb/ft\ jam}{0,001\ lb/ft\ jam})^{0,14}$ $= 2,3760$ h_{io} sebenarnya = 131,4715 btu/(hr)(ft²)(°F) × 2,3760 $= 312,3763\ btu/(hr)(ft^2)(°F)$

11. Clean overall coefficient

$U_c = \dfrac{h_{io} \times h_o}{h_{io} + h_o}$ Pers 6.7 DQ Kern

$$U_c = \frac{312{,}3763 \frac{btu}{hr\ ft^2 °F} \times 1500 \frac{btu}{hr\ ft^2 °F}}{312{,}3763 \frac{btu}{hr\ ft^2 °F} + 1500 \frac{btu}{hr\ ft^2 °F}} = 258{,}5360 \frac{btu}{hr\ ft^2 °F}$$

12. Design overall coefficient

$$\frac{1}{U_d} = \frac{1}{U_c} + R_d \quad \text{Pers 6.10 DQ Kern}$$

$$\frac{1}{U_d} = \frac{1}{258{,}5360 \frac{btu}{hr\ ft^2 °F}} + 0{,}001\ ft^2\ hr\ °F/btu$$

$$U_d = 204{,}0816 \frac{btu}{hr\ ft^2 °F}$$

13. Surface area required

$$A = \frac{Q}{U_d \times LMTD} \quad \text{DQ. Kern Pers 7.42 Hal 144}$$

$$A = \frac{169.926{,}2141\ btu/jam}{204{,}0816\ btu/jam\ ft^2\ °F \times 334{,}5725\ °F}$$

$$A = 2{,}4887\ ft^2$$

14. Menghitung jumlah *hairpin*

$$\textit{Required length} = \frac{A}{a''}$$

$$\textit{Required length} = \frac{2{,}4887\ ft^2}{0{,}622\ ft^2/ft}$$

Required length = 4,0011 ft

Digunakan Panjang pipa untuk *double pipe heat exchanger* : 12 ft

1 *hairpin* terdiri dari 2 pipa, maka jumlah *hairpin* yang diperlukan adalah :

$$\textit{Hairpin} = \frac{L}{2 \times L_H}$$

$$Hairpin = \frac{4{,}0011 \text{ ft}}{2 \times 12 \text{ ft}}$$

Hairpin = 0,1667

≈ 1

Koreksi Panjang pipa

L koreksi = 2 × L *Hairpin* × Banyak *Hairpin*

L koreksi = 2 × 4,0011 × 1

L koreksi = 8,0022 ft

15. *Actual design overall coefficient*

actual surface = *required length* × a''

actual surface = 8,0022 ft × 0,622 ft^2/ft = 4,9774 ft^2

$$U_d \; actual = \frac{Q}{A \times LMTD}$$

$$U_d actual = \frac{169.926{,}2141 \text{ btu/jam}}{4{,}9774 \text{ ft}^2 \times 334{,}5725 \text{ °F}}$$

U_d *actual* = 102,0393 btu/jam ft^2 °F

Asumsi benar karena U_d *actual* < U_d desain

R_d sebenarnya

$$R_d = \frac{U_c - U_d}{U_c \times U_d}$$

$$R_d = \frac{258{,}5360 \text{ btu/jam ft}^2 \text{ °F} - 102{,}0393 \text{ btu/jam ft}^2 \text{ °F}}{258{,}5360 \text{ btu/jam ft}^2 \text{ °F} \times 102{,}0393 \text{ btu/jam ft}^2 \text{ °F}}$$

R_d = 0,0059 ft^2 jam °F/btu

R_d yang diperlukan = 0,001 ft^2 jam °F/btu

R_d sebenarnya > R_d yang diperlukan (memenuhi)

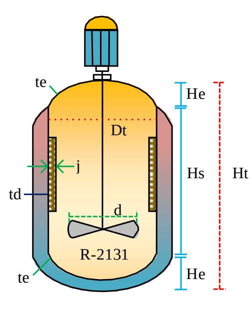
16. Pressure drop

Annulus (Steam)	***Inner Pipe (KOH)***
1. $D_e' = D_2 - D_1$ Pers 6.4 DQ Kern $D_e' = 0{,}2557\ ft - 0{,}1983\ ft$ $D_e' = 0{,}0574\ ft$ $Re_a' = \frac{D_e' \times G_a}{\mu}$ $Re_a' = \frac{0{,}0574\ ft \times 10.985{,}9220\ lb/hr\ ft^2}{0{,}0411\ lb/ft\ hr}$ $Re_a' = 15.342{,}8692$ (Turbulen) *Fanning factor* untuk turbulen : $f = 0{,}0035 + \frac{0{,}264}{(DG/\mu)^{0{,}42}}$ Pers 3.47b DQ Kern $f = 0{,}0035 + \frac{0{,}264}{(15.342{,}8692)^{0{,}42}}$ $f = 0{,}0081$ 2. $\Delta F_a = \frac{4 \times f \times Ga^2 \times L}{2 \times g \times \rho^2 \times D_e}$ Pers 6.14 DQ Kern $g = 4{,}18 \times 10^8 ft/hr^2$ $\rho = 57{,}1316\ lb/ft^3$ $\Delta F_a = \frac{4 \times 0{,}0081 \times (10.985{,}9220\ lb/hr\ ft)^2 \times 8\ ft}{2 \times 4{,}18 \times 10^8 ft/hr \times (57{,}1316\ lb/ft^3)^2 \times 0{,}0574\ ft}$ $\Delta F_a = 0{,}0002\ ft$ 3. $V = \frac{G}{3600\rho}$ $V = \frac{10.985{,}9220\ lb/hr\ ft^2}{3600 \times 57{,}1316\ lb/ft^3}$ $V = 0{,}0534\ ft/s$	1. $Re_p = 14517{,}6242$ (Turbulen) *Fanning factor* untuk turbulen : $f = 0{,}0035 + \frac{0{,}264}{(DG/\mu)^{0{,}42}}$ Pers 3.47b DQ Kern $f = 0{,}0035 + \frac{0{,}264}{(14517{,}6242)^{0{,}42}}$ $f = 0{,}0082$ 2. $\Delta F_p = \frac{4 \times f \times Gp^2 \times L}{2 \times g \times \rho^2 \times D_e}$ Pers 6.14 DQ Kern $g = 4{,}18 \times 10^8 ft/hr^2$ $\rho = 57{,}1316\ lb/ft^3$ $\Delta F_p = \frac{4 \times 0{,}0082 \times (16.851{,}5661\ lb/hr\ ft)^2 \times 8\ ft}{2 \times 4{,}18 \times 10^8 ft/hr \times (57{,}1316\ lb/ft^3)^2 \times 0{,}1723\ ft}$ $\Delta F_p = 0{,}0001\ ft$ 3. $\Delta P_p = \frac{(\Delta Fp)\rho}{144}$ Pers 3.45 DQ Kern $\Delta P_a = \frac{(0{,}0001\ ft)\ 57{,}1316\ lb/ft^3}{144}$ $\Delta P_a = 0{,}0001$ psi ΔP_a yang diizinkan=10 psi 0,0001 psi < 10 psi (Memenuhi)

$\Delta F_l = \dfrac{V^2}{2g}$ $\Delta F_l = \dfrac{(0{,}0534\ ft/s)^2}{2\times 32{,}2\ ft/s^2}$ $\Delta F_l = 0{,}00004$ ft 4. $\Delta P_a = \dfrac{(\Delta Fa + \Delta F1)\rho}{144}$ Pers 3.45 DQ Kern $\Delta P_a = \dfrac{(0{,}0002\ ft + 0{,}00004\ ft)\ 57{,}1316\ lb/ft^3}{144}$ ΔP_a= 0,0001 psi ΔP_a yang diizinkan=10 psi 0,0001 psi < 10 psi (Memenuhi)	

14) *Netralizer Reactor* (R-2131)

Fungsi	: Tempat mereaksikan asam lemak dengan KOH untuk mendapatkan sabun cair
Tipe	: Silinder vertikal dengan alas dan tutup *elipsoidal*
Jenis Reaktor	: *Continous stirred tank reactor*
Bahan konstruksi	: *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*
Jumlah	: 1 unit
Sifat bahan	: Tidak volatil, tidak korosif dan tidak higroskopis
Fasa	: Cair



Gambar LC-16. *Netralizer Reactor*

Data:

- Laju alir umpan : 2.313,865 kg/jam : 5.101,1468 lb/jam
- Densitas campuran : 1.007,5755 kg/m^3 : 62,9029 lb/ft^3
- Tekanan : 1 atm
- Viskositas Campuran : 1,6089 cP : 0,0011 lb/ft.s
- *Space time* : 30 menit : 0,5 jam

1. Kapasitas Reaktor

$$V_p = \frac{m \times \tau}{\rho}$$

$$V_p = \frac{2.313,865 \text{ kg/jam} \times 0,5 \text{ jam}}{1.007,5755 \text{ kg/m}^3}$$

$$V_p = 1,1483 \text{ m}^3$$

$$= 40,5511 \text{ ft}^3$$

$$= 70.073,5652 \text{ in}^3$$

$$= 303,3487 \text{ gal}$$

Dengan Mempertimbangkan faktor keamanan 20 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$$V_p = 0,8\ V_t$$

$$V_t = \frac{V_p}{0,8}$$

$$V_t = \frac{1,1483 \text{ m}^3}{0,8}$$

$$V_t = 1,4354 \text{ m}^3$$

$$= 50,6897 \text{ ft}^3$$

$$= 87.593,4821 \text{ in}^3$$

$$= 379,1925 \text{ gal}$$

2. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1,1775\ D_t^3$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0,1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + 2\ V_e$

$V_t = 1,1775\ D_t^3 + 2\ (0,1308\ D_t^3)$

$V_t = 1,4391\ D_t^3$

$D_t^3 = \frac{V_t}{1,4391}$

$D_t^3 = \frac{1,4354\ m^3}{1,4391}$

$D_t = \sqrt[3]{\frac{1,4354\ m^3}{1,4391}}$

$D_t = 0,9991$ m

= 3,2770 ft

= 39,3346 in

d. Tinggi Silinder

$H_s = 1,5\ D_t$

$H_s = 1{,}5 \times 0{,}9991$ m

$H_s = 1{,}4987$ m

$= 4{,}9157$ ft

$= 59{,}0038$ in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 0{,}9991$ m

$H_e = 0{,}2498$ m

$= 0{,}8193$ ft

$= 9{,}8346$ in

f. Tinggi Tangki

$H_t = H_s + (2\ H_e)$

$H_t = 1{,}4987\ \text{m} + (2 \times 0{,}2498\ \text{m})$

$H_t = 1{,}9983$ m

g. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s + (2\ H_e))}{V_t}$$

$$H_c = \frac{1{,}1483\ \text{m}^3 \times (1{,}4987\ \text{m} + (2 \times 0{,}2498\ \text{m}))}{1{,}4354\ \text{m}^3}$$

$H_c = 1{,}5986$ m

$= 5{,}2434$ ft

$= 62{,}9369$ in

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

P_c = 1.007,5755 kg/m^3× 9,81 m/s^2 × 1,5986 m

P_c = 15.801,0670 kg.m/s^2

= 0,1533 atm

= 2,2529 psi

i. Tekanan Desain

P_d = P_{op}+ P_c

P_d = 1 atm + 0,1533 atm

P_d = 1,1533 atm

= 16,9535 psi

P_d = 16,9535 psi

R = 19,6673 in

S = 18700 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment*, *Table 18.4*, *Page 658*)

$$t_d = \frac{16,9535 \text{ psi} \times 19,6673 \text{ in}}{18700 \text{ psi} \times 0,85 - 0,6 \times 16,9535 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2210 in

= 0,0056 m

= 0,0184 ft

= 5,6134 mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0,2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{16,9535 \text{ psi} \times 39,3346 \text{ in}}{2 \times 18700 \text{ psi} \times 0,85 - 0,2 \times 16,9535 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2210 in

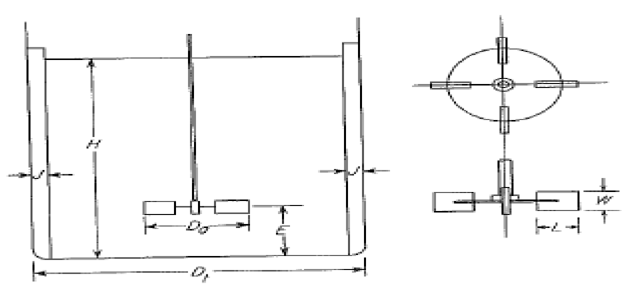
= 0,0056 m

= 0,0184 ft

= 5,6134 mm

3. Desain Pengaduk

Viskositas umpan < 4000 cP, maka dipilih *propeller* berdaun tiga (Kecepatan 1800 rpm) (*Walas - Selection Design & Chemical Process Equipment ed 1st, Page 288*).



Gambar LC-17. Desain Pengaduk *Netralizer Reactor*

a. Diameter Pengaduk

$$d = \frac{D_t}{3}$$

$$d = \frac{0{,}9991 \text{ m}}{3}$$

d = 0,3330 m

= 1,0922 ft

b. Panjang Daun Pengaduk

$$L = \frac{d}{4}$$

$$L = \frac{0{,}3330 \text{ m}}{4}$$

L = 0,0833 m

= 0,2732 ft

c. Lebar Daun Pengaduk

$$W = \frac{d}{5}$$

$$W = \frac{0{,}3330 \text{ m}}{5}$$

W = 0,0666 m

= 0,2184 ft

d. Tinggi Pengaduk Dari Dasar Tangki

$$E = \frac{D_t}{3}$$

$$E = \frac{0{,}9991 \text{ m}}{3}$$

E = 0,3330 m

= 1,0922 ft

e. Lebar *Baffle*

$$J = \frac{D_t}{12}$$

$$J = \frac{0{,}9991 \text{ m}}{12}$$

$J = 0{,}0833$ m

$= 0{,}2732$ ft

f. Kecepatan Putar Pengaduk

Berdasarkan persamaan 6-18 *Robert Treyball-Mass Transfer Operation,* kecepatan putar pengaduk dapat dihitung dengan persamaan berikut.

Dengan $g_c = 32{,}2$ ft/s^2

σ = 72,75 dyn/cm (*Mc.cabe – Unit Operation Of Chemical Engineering 5th Page 274*).

= 0,0537 lb/ft

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

$$\frac{N_d}{\left(\frac{0{,}0537 \text{ lb/ft} \times 32{,}2 \text{ ft/s}^2}{62{,}9029 \text{ lb/ft}^3}\right)^{0{,}25}} = 1{,}22 + 1{,}25\left(\frac{3{,}2770 \text{ ft}}{1{,}0922 \text{ ft}}\right)$$

$N_d = 2{,}4905$ rps

g. Daya Pengadukan

Berdasarkan persamaan 9-17 *Mc.cabe – Unit Operation Of Chemical Engineering 5^{t},* bilangan *reynold* dapat dihitung dengan persamaan berikut.

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

$$N_{Re} = \frac{62{,}9029 \text{ lb/ft}^3 \times 2{,}4905 \text{ rps} \times (1{,}0922 \text{ ft})^2}{0{,}0011 \text{ lb/ft.s}}$$

N_{Re} = 169.890,4135

Karena Nre > 10.000, maka berdasarkan persamaan 9.24 *Mc.cabe – Unit Operation Of Chemical Engineering 5^{t}*, daya pengadukan menggunakan dapat dihitung dengan persamaan berikut.

Dengan K_T = 0,87 (*Mc. Cabe & Smith - Unit Operations Of Chemical Engineering 5th, Page 254*)

$$P = \frac{K_T N^3 D_a^5 \rho}{g_c}$$

$$P = \frac{0{,}87 \times (2{,}4905\ rps)^3 \times (1{,}0922\ ft)^5 \times 62{,}9029\ lb/ft^3}{32{,}2\ ft/s^2}$$

P = 40,8042 ft.lbf/s

P = 0,0742 HP

h. Daya Motor

Efisiensi Motor = 80%

$$\text{Daya Motor} = \frac{0{,}0742\ HP}{80\%}$$

Daya Motor = 0,0928 HP

≈ 0,5 HP

4. Desain Pendingin

Data:

- Temperatur Umpan : 80 ^oC, : 176 ^oF
- Temperatur Pendingin : 28 ^oC, : 82,4 ^oF
- Densitas Pendingin : 1000 kg/m^3 : 62,43 lb/ft^3 (*engineering toolbox.com*)
- Massa Pendingin : 113,6108 kg/jam : 250,4664 lb/jam
- Q : 1.136,1078 kkal/jam : 4.508,0758 btu/jam
- ΔT : 93,6 ^oF

Karena massa steam lebih kecil dari massa umpan, maka digunakan *jacket.*

a. Luas Permukaan Perpindahan Panas

$$A = \frac{Q}{U_d \times \Delta T}$$

Dengan U_d = 200 W/m^{2}C Engineeringpage.com

= 35,2 Btu/ft^2 F hr

$$A = \frac{4.508,0758 \text{ btu/hr}}{35,2 \text{ Btu/ft}^2 \text{ F hr} \times 93,6\ ^oF}$$

= 1,3683 ft^2

b. Tinggi *Jacket*

Asumsi jarak *jacket* : 5 in : 0,1270 m

$H_j = H_c + t_e$ + Jarak jacket

H_j = 62,9369 in + 0,2210 in + 5 in

H_j = 68,1579 in

= 1,7312 m

= 5,6783 ft

c. Diameter *Jacket*

- Diameter Tangki

  $D_r = D_t + (2 \times t_d)$

  D_r = 39,3346 in + (2 × 0,2210 in)

  D_r = 39,7766 in

  = 1,0103 m

  = 3,3138 ft

- Diameter Luar *Jacket*

  $D_j = D_r$ + (2 × jarak *jacket*)

D_j = 39,7766 in + (2 × 5 in)

D_j = 49,7766 in

= 1,2643 m

= 4,1469 ft

d. Tekanan Hidrostatik Pada *Jacket*

$P_h = \rho \times g \times H_c$

P_h = 1000 kg/m^3× 9,81 m/s^2 × 1,5986 m

P_h = 15.682,2660 kg.m/s^2

= 0,1521 atm

= 2,2352 psi

e. Tekanan Desain

$P_d = P_{op} + P_h$

P_d = 1 atm + 0,1521 atm

P_d = 1,1521 atm

= 16,9311 psi

f. Tebal Dinding *Jacket*

$t_{dj} = D_j - D_r$

t_{dj} = 1,2643 m - 1,0103 m

t_{dj} = 0,2540 m

g. Volume Pendingin

$$V_s = \frac{Massa_{cw}}{Densitas_{cw}}$$

$$V_s = \frac{113{,}6108\ kg/jam}{1000\ kg/m^3} = 0{,}1136\ m^3/jam$$

15) *Cooler* 2 (CO-2142)

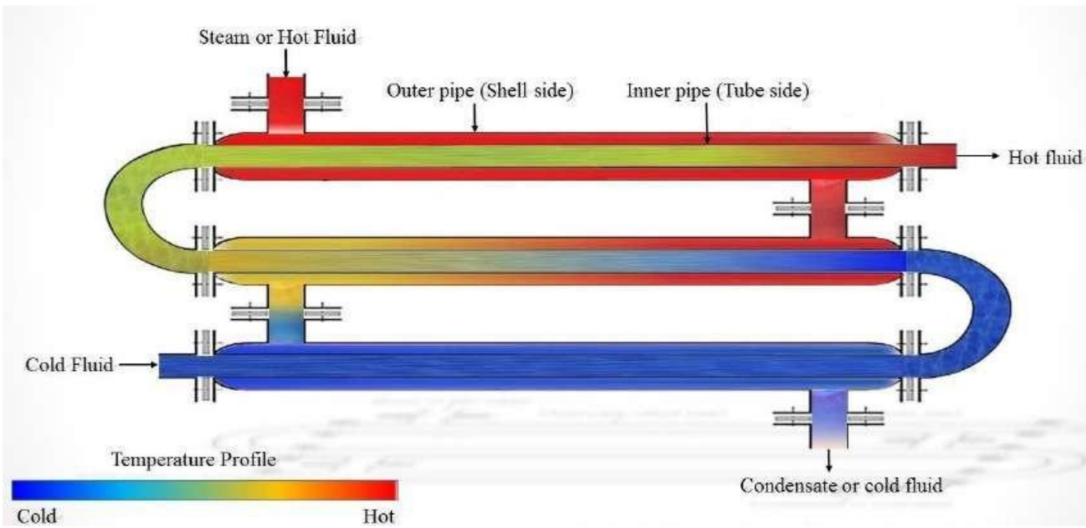
Fungsi : Untuk mendinginkan produk sabun cair dari *netralizer reactor*

Tipe : *Double Pipe*

Bahan konstruksi : *Dupllex Stainless steel* Tipe-2205

Jumlah : 1 unit

Fasa : Cair



Gambar LC-18. *Cooler* 2

Data:

- Laju alir *hot fluid* (sabun cair): 2.313,8652 kg/jam : 5.101,1472 lb/jam
- Laju alir *cold fluid* (*cooling water*): 7.383,2737 kg/jam : 16.277,1652 lb/jam
- Q : 73.832,7375 kkal/jam : 292.968,3024 btu/jam
- Tekanan : 1 atm
- T_1 : 329,23 ^oC : 624,614 ^oF
- T_2 : 30 ^oC : 86 ^oF
- t_1 : 28 ^oC : 82,4 ^oF
- t_2 : 38 ^oC : 100,4 ^oF

1. Menentukan Jenis *Heater*

a. Menghitung LMTD

Hot fluid		*Cold Fluid*	*Difference*	
176	***High Temperatur***	100,4	75,6	**Δt_2**
86	***Low Temperatur***	82,4	3,6	**Δt_1**
			72	**$\Delta t_2 - \Delta t_1$**

$$LMTD = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln\left(\frac{T_1 - t_2}{T_2 - t_1}\right)}$$ DQ Kern, Pers 6.17 hal 117

$$LMTD = \frac{(176\ °F - 100{,}4\ °F) - (86\ °F - 82{,}4\ °F)}{\ln\left(\frac{176\ °F - 100{,}4\ °F}{86\ °F - 82{,}4\ °F}\right)}$$

$= 23{,}6492\ °F$

b. Luas Area Perpindahan Panas

Diketahui viskositas *hot fluid* : 1,61 cP

Berdasarkan *Table 8 - DQ Kern Page 840,* diperoleh :

Coolers

Hot fluid	Cold fluid	Overall U_D
Water	Water	250–500§
Methanol	Water	250–500§
Ammonia	Water	250–500§
Aqueous solutions	Water	250–500§
Light organics*	Water	75–150
Medium organics†	Water	50–125
Heavy organics‡	Water	5–75‖
Gases	Water	2–50¶
Water	Brine	100–200
Light organics	Brine	40–100

Maka dipilih U_d = 300 Btu/jam ft^2 °F

Maka,

$$A = \frac{Q}{U_d \times LMTD}$$ DQ. Kern Pers 7.42 Hal 144

$$A = \frac{292.968,3024 \text{ btu/jam}}{300 \text{ Btu/jam ft}^2 \text{ °F} \times 23,6492 \text{ °F}}$$

$A = 41,2936 \text{ ft}^2$

Karena nilai A < 200 ft^2 maka tipe *heat exchanger* yang digunakan adalah *double pipe* (*DQ Kern Page 103*)

2. Pemilihan Ukuran *Double Pipe*

Berdasarkan *Table 6.2 DQ. Kern Page 110* maka dipilih ukuran *double pipe* berikut ini.

	Outer pipe	***Inner Pipe***	**Satuan**
IPS	3	2	In
Sch	40	40	
OD	3,5	2,38	In
ID	3,068	2,067	In
a''	0,917	0,622	ft^2/ft

3. Menentukan *caloric temperature*

$T_{av} = \frac{T_1 + T_2}{2}$ DQ.Kern Hal 113

$T_{av} = \frac{176 \text{ °F} + 86 \text{ °F}}{2}$

$= 131 \text{ °F}$

$t_{av} = \frac{t_1 + t_2}{2}$ DQ.Kern Hal 113

$t_{av} = \frac{82,4 \text{ °F} + 100,4 \text{ °F}}{2}$

$= 91 \text{ °F}$

***Annulus* (Sabun Cair)**	***Inner Pipe (Cooling Water)***
4. *Flow area*	4. *Flow area*
$a_a = \frac{\pi(D_2^2 - D_1^2)}{4}$ DQ. Kern Pers 6.3	$a_p = \frac{\pi(D^2)}{4}$ DQ. Kern Hal 111
$a_a = \frac{3,14\ ((0,2557\ ft)^2 - (0,1983\ ft)^2)}{4}$	$a_p = \frac{3,14\ ((0,1723\ ft)^2)}{4}$
$= 0,0205\ ft^2$	$= 0,1753\ ft^2$
Equivalent diameter	
$D_e = \frac{(D_2^2 - D_1^2)}{D_1}$ DQ. Kern Hal 111	
$D_e = \frac{(0,2557\ ft)^2 - (0,1983\ ft)^2}{0,1983\ ft}$	
$= 0,1314\ ft$	
5. Laju alir massa	5. Laju alir massa
$G_a = \frac{W}{a_a}$ DQ. Kern Hal 114	$G_p = \frac{W}{a_p}$ DQ. Kern Hal 114
$G_a = \frac{5.101,1472\ lb/jam}{0,0205\ ft^2}$	$G_p = \frac{16.277,1652\ lb/jam}{0,1353\ ft^2}$
$= 248.836,4488\ lb/jam\ ft^2$	$= 120.304,2513\ lb/jam\ ft^2$
6. Bilangan Reynold	6. Bilangan Reynold
T_{av} = 131 °F	T_{av} = 91 °F
μ *top product* = 1,1 cP	μ *Cooling water* = 0,8 cP
= 2,6611 lb/ft jam	= 1,9354 lb/ft jam
DQ. Kern Hal 825	DQ. Kern Hal 823

	X	Y		X	Y
Ethyl chloride	14.8	6.0	Toluene	13.7	10.4
Ethyl ether	14.5	5.3	Trichloroethylene	14.8	10.5
Ethyl formate	14.2	8.4	Turpentine	11.5	14.9
Ethyl iodide	14.7	10.3	Vinyl acetate	14.0	8.8
Ethylene glycol	6.0	23.6	Water	10.2	13.0
Formic acid	10.7	15.8	Xylene, ortho	13.5	12.1
Freon-11	14.4	9.0	Xylene, meta	13.9	10.6
Freon-12	16.8	5.6	Xylene, para	13.9	10.9

* From Perry, J. H., "Chemical Engineers' Handbook," 3d ed., McGraw-Hill Book Company, Inc.,

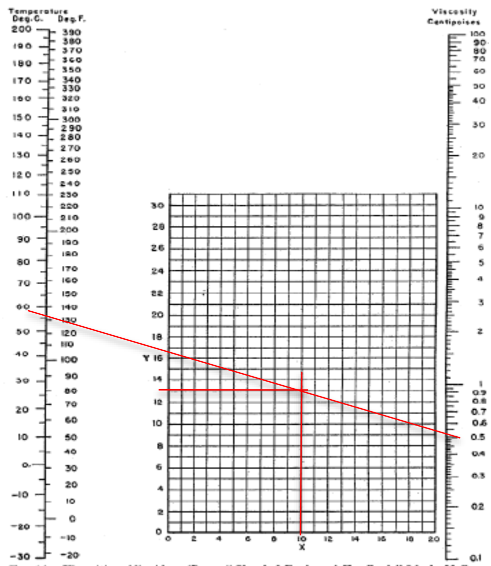


FIG. 14. Viscosities of liquids. (Perry, "Chemical Engineers' Handbook," 3d ed., McGraw

$$R_{ea} = \left(\frac{D_e \times G_a}{\mu}\right) \quad \text{DQ. Kern Hal 114}$$

$$R_{ea} = \left(\frac{0{,}1314 \text{ ft} \times 248.836{,}4488 \text{ lb/jam ft}^2}{2{,}6611 \text{ lb/ft jam}}\right)$$

$= 12.287{,}0653$

7. jH

jH = 80 DQ. Kern Hal 834

	X	Y		X	Y
Ethyl chloride	14.8	6.0	Toluene	13.7	10.4
Ethyl ether	14.5	5.3	Trichloroethylene	14.8	10.5
Ethyl formate	14.2	8.4	Turpentine	11.5	14.9
Ethyl iodide	14.7	10.3	Vinyl acetate	14.0	8.8
Ethylene glycol	6.0	23.6	Water	10.2	13.0
Formic acid	10.7	15.8	Xylene, ortho	13.5	12.1
Freon-11	14.4	9.0	Xylene, meta	13.9	10.6
Freon-12	16.8	5.6	Xylene, para	13.9	10.9

* From Perry, J. H., "Chemical Engineers' Handbook," 3d ed., McGraw-Hill Book Company, Inc.,

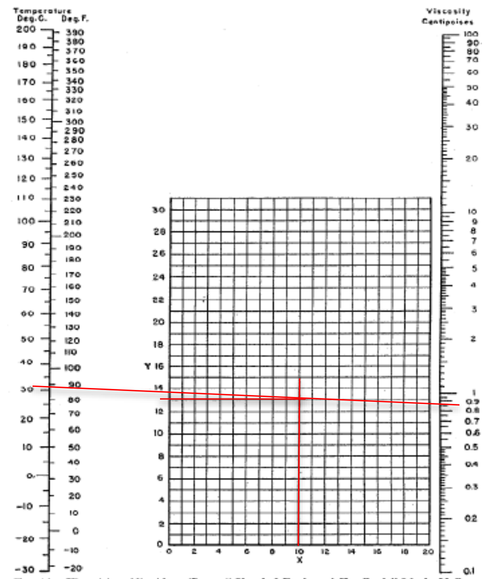


FIG. 14. Viscosities of liquids. (Perry, "Chemical Engineers' Handbook," 3d ed., McGraw

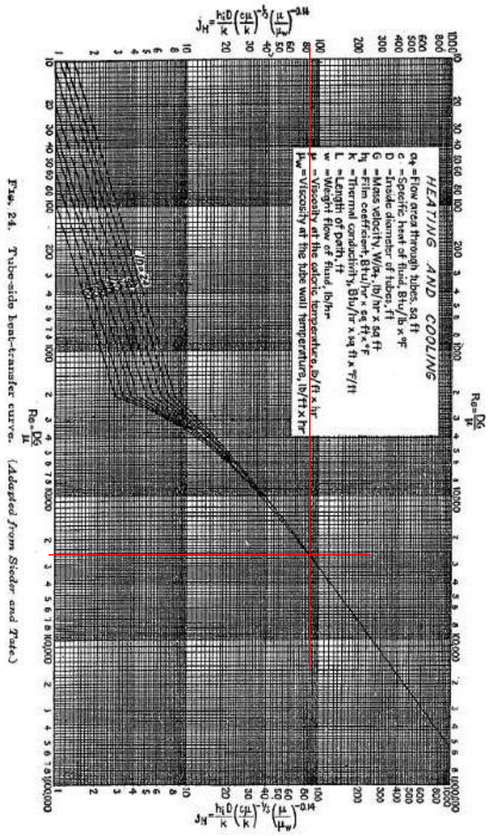
$$R_{ep} = \left(\frac{D \times G_p}{\mu}\right) \quad \text{DQ. Kern Hal 114}$$

$$R_{ep} = \left(\frac{0{,}1723 \text{ ft} \times 120.304{,}2513 \text{ lb/jam ft}^2}{1{,}9354 \text{ lb/ft jam}}\right)$$

$= 25.910{,}5281$

7. jH

jH = 250 DQ. Kern Hal 834



8. Konduktivitas dan kapasitas panas

Pada t_{av}= 131 °F

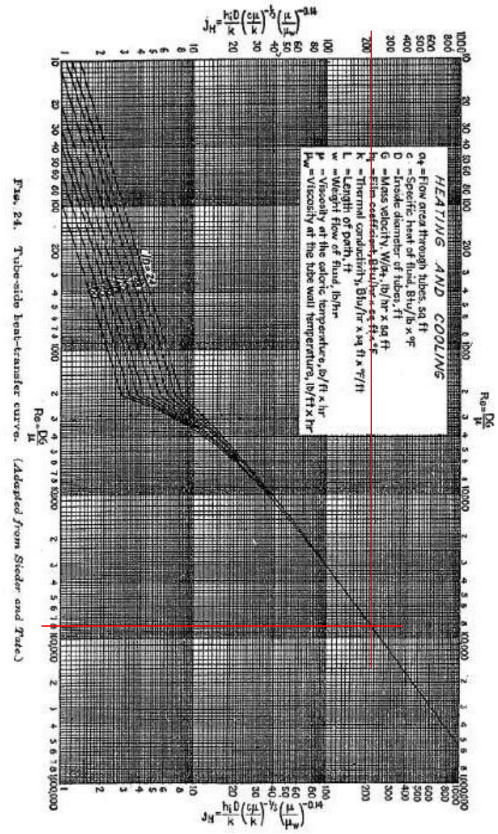
c = 0,2 btu/lb °F

k = 0,3768 btu/(hr)(ft^2)(°F)

DQ. Kern Hal 800

$$\left(\frac{c\,\mu}{k}\right)^{1/3} = \left(\frac{0{,}2\,\frac{btu}{lb\,°F} \times 2{,}6611\,\frac{lb}{hr\,ft}}{0{,}3768\,\frac{Btu}{(hr)\,(ft^2)(°F/ft)}}\right)^{\frac{1}{3}}$$

= 1,1220 ft



8. Konduktivitas dan kapasitas panas

Pada t_{av}= 91 °F

c = 0,6 btu/lb °F

k = 0,3560 btu/(hr)(ft^2)(°F)

DQ. Kern Hal 800

$$\left(\frac{c\,\mu}{k}\right)^{1/3} = \left(\frac{0{,}6\,\frac{btu}{lb\,°F} \times 1{,}9354\,\frac{lb}{hr\,ft}}{0{,}3560\,\frac{Btu}{(hr)\,(ft^2)(°F/ft)}}\right)^{\frac{1}{3}}$$

= 1,0695 ft

9. h_o	9. h_i
$h_o = jH \frac{k}{D} \left(\frac{c\,\mu}{k}\right)^{\frac{1}{3}} \left(\frac{\mu}{\mu_w}\right)^{0,14}$ pers 6.15a DQ Kern	$h_i = jH \frac{k}{D} \left(\frac{c\,\mu}{k}\right)^{\frac{1}{3}} \left(\frac{\mu}{\mu_w}\right)^{0,14}$ pers 6.15a DQ Kern
$h_o = (80) \dfrac{0,3768 \frac{btu}{(hr)\,(ft^2)(°F/ft)}}{0,1314\ ft} (1,6580\ ft)(1)$	$h_i = (250) \dfrac{0,3560 \frac{btu}{(hr)\,(ft^2)(°F/ft)}}{0,1723\ ft} (1,0695\ ft)(1)$
$= 257,3940\ btu/(hr)(ft^2)(°F)$	$= 552,4405\ btu/(hr)(ft^2)(°F)$
10. Koreksi h_o	10. Koreksi h_i
$h_{io} = h_i \frac{ID}{OD}$ pers 6.15 DQ Kern	$h_{io} = h_i \frac{ID}{OD}$ pers 6.15 DQ Kern
$h_{io} = 552,4405 \frac{btu}{(hr)\,(ft^2)(°F)} \frac{0,1723\ ft}{0,1983\ ft}$	$h_{io} = 552,4405 \frac{btu}{(hr)\,(ft^2)(°F)} \frac{0,1723\ ft}{0,1983\ ft}$
$= 479,7876\ btu/(hr)(ft^2)(°F)$	$= 479,7876\ btu/(hr)(ft^2)(°F)$
Temperatur Dinding	Temperatur Dinding
$t_w = t_{avg} + \frac{h_o}{h_{io}+h_o} \times (T_{avg} - t_{avg})$	$t_w = t_{avg} + \frac{h_o}{h_{io}+h_o} \times (T_{avg} - t_{avg})$
$t_w = 91\ °F + \frac{120,0988\ btu/hr\ ft^2\ °F}{(479,7876+120,0988)\ btu/(hr)(ft^2)(°F)} \times (131-91)°F$	$t_w = 91\ °F + \frac{120,0988\ btu/hr\ ft^2\ °F}{(479,7876+120,0988)\ btu/(hr)(ft^2)(°F)} \times (131-91)°F$
$= 105\ °F$	$= 105\ °F$
Pada $t_w = 105\ °F$	Pada $t_w = 105\ °F$
$\mu = 0,01$ lb/ft jam	$\mu = 0,001$ lb/ft jam
Maka,	Maka,
$\phi_p = \left(\frac{\mu}{\mu_w}\right)^{0,14}$	$\phi_p = \left(\frac{\mu}{\mu_w}\right)^{0,14}$
$\phi_p = \left(\frac{2,6611\ lb/ft\ jam}{0,01\ lb/ft\ jam}\right)^{0,14}$	$\phi_p = \left(\frac{1,9354\ lb/ft\ jam}{0,001\ lb/ft\ jam}\right)^{0,14}$
$= 2,1835$	$= 2,5149$
h_o sebenarnya = 257,3940 btu/(hr)(ft^2)(°F) × 2,1835	h_{io} sebenarnya = 479,7876 btu/(hr)(ft^2)(°F) × 2,5149
$= 562,4831\ btu/(hr)(ft^2)(°F)$	$= 1.206,6178\ btu/(hr)(ft^2)(°F)$

11. Clean overall coefficient

$$U_c = \frac{h_{io} \times h_o}{h_{io} + h_o} \quad \text{Pers 6.7 DQ Kern}$$

$$U_c = \frac{1.206,6178 \frac{btu}{hr\ ft^2 °F} \times 562,4831 \frac{btu}{hr\ ft^2 °F}}{1.206,6178 \frac{btu}{hr\ ft^2 °F} + 562,4831 \frac{btu}{hr\ ft^2 °F}} = 383,6424 \frac{btu}{hr\ ft^2 °F}$$

12. Design overall coefficient

$$\frac{1}{U_d} = \frac{1}{U_c} + R_d \quad \text{Pers 6.10 DQ Kern}$$

$$\frac{1}{U_d} = \frac{1}{383,6424 \frac{btu}{hr\ ft^2 °F}} + 0,001\ ft^2\ hr\ °F/btu$$

$$U_d = 277,7778 \frac{btu}{hr\ ft^2 °F}$$

13. Surface area required

$$A = \frac{Q}{U_d \times LMTD} \quad \text{DQ. Kern Pers 7.42 Hal 144}$$

$$A = \frac{292.968,3024\ btu/jam}{277,7778\ btu/jam\ ft^2\ °F \times 23,6492\ °F}$$

$A = 44,5971\ ft^2$

14. Menghitung jumlah *hairpin*

Required length = $\frac{A}{a''}$

Required length = $\frac{44,5971\ ft^2}{0,622\ ft^2/ft}$

Required length = 71,6995 ft

Digunakan Panjang pipa untuk *double pipe heat exchanger* : 12 ft

1 *hairpin* terdiri dari 2 pipa, maka jumlah *hairpin* yang diperlukan adalah :

$$Hairpin = \frac{L}{2 \times L_H}$$

$$Hairpin = \frac{71{,}6995 \text{ ft}}{2 \times 12 \text{ ft}}$$

Hairpin = 2,9875

≈ 3

Koreksi Panjang pipa

L koreksi = 2 × L *Hairpin* × Banyak *Hairpin*

L koreksi = 2 × 12 ft × 3

L koreksi = 72 ft

15. *Actual design overall coefficient*

actual surface = *required length* × a"

actual surface = 72 ft × 0,622 ft^2/ft = 44,784 ft^2

$$U_d\ actual = \frac{Q}{A \times LMTD}$$

$$U_d actual = \frac{292.968{,}3024 \text{ btu/jam}}{44{,}784 \text{ ft}^2 \times 23{,}6492 \text{ °F}}$$

U_d *actual* = 276,6185 btu/jam ft^2 °F

Asumsi benar karena U_d *actual* < U_d desain

R_d sebenarnya

$$R_d = \frac{U_c - U_d}{U_c \times U_d}$$

$$R_d = \frac{383{,}6424 \text{ btu/jam ft}^2 \text{ °F} - 276{,}6185 \text{ btu/jam ft}^2 \text{ °F}}{383{,}6424 \text{ btu/jam ft}^2 \text{ °F} \times 276{,}6185 \text{ btu/jam ft}^2 \text{ °F}}$$

R_d = 0,001 ft^2 jam °F/btu

R_d yang diperlukan = 0,001 ft^2 jam °F/btu

R_d sebenarnya = R_d yang diperlukan (memenuhi)

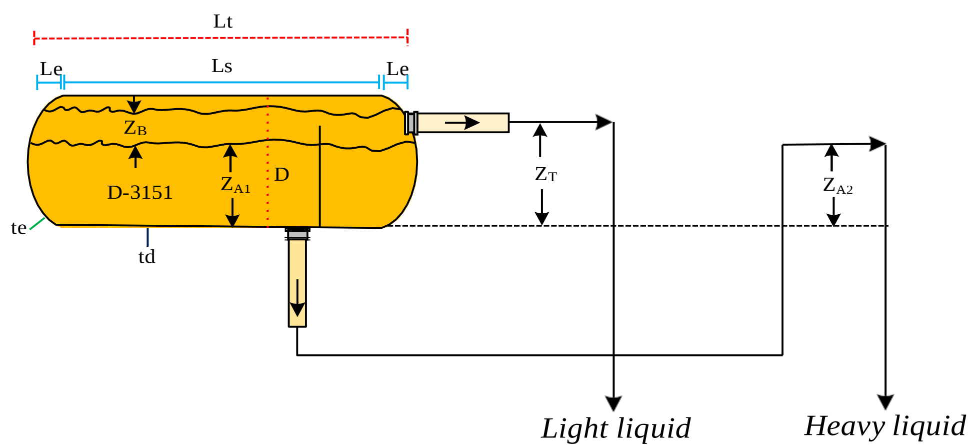
16. Pressure drop

Annulus **(Sabun cair)**	***Inner Pipe (Cooling water)***
1. $D_e' = D_2 - D_1$ Pers 6.4 DQ Kern $D_e' = 0{,}2557 \text{ ft} - 0{,}1983 \text{ ft}$ $D_e' = 0{,}0574 \text{ ft}$ $Re_a' = \frac{D_e' \times G_a}{\mu}$ $Re_a' = \frac{0{,}0574 \text{ ft} \times 248.836{,}4488 \text{ lb/hr ft}^2}{2{,}6611 \text{ lb/ft hr}}$ $Re_a' = 5.367{,}4090$ (turbulen) *Fanning factor* untuk turbulen : $f = 0{,}0035 + \frac{0{,}264}{(DG/\mu)^{0{,}42}}$ Pers 3.47b DQ Kern $f = 0{,}0035 + \frac{0{,}264}{(5.367{,}4090)^{0{,}42}}$ $f = 0{,}0107$ 2. $\Delta F_a = \frac{4 \times f \times Ga^2 \times L}{2 \times g \times \rho^2 \times D_e}$ Pers 6.14 DQ Kern $g = 4{,}18 \times 10^8 \text{ft/hr}^2$ $\rho = 62{,}9029 \text{ lb/ft}^3$ $\Delta F_a = \frac{4 \times 0{,}0170 \times (248.836{,}4488 \text{ lb/hr ft})^2 \times 72 \text{ ft}}{2 \times 4{,}18 \times 10^8 \text{ft/hr} \times (62{,}9029 \text{ lb/ft}^3)^2 \times 0{,}0574 \text{ ft}}$ $\Delta F_a = 1{,}0050 \text{ ft}$ 3. $V = \frac{G}{3600\rho}$ $V = \frac{248.836{,}4488 \text{ lb/hr ft}^2}{3600 \times 38{,}4046 \text{ lb/ft}^3}$ $V = 1{,}0989 \text{ ft/s}$	4. $Re_p = 6.9094{,}7417$ *Fanning factor* untuk turbulen : $f = 0{,}0035 + \frac{0{,}264}{(DG/\mu)^{0{,}42}}$ Pers 3.47b DQ Kern $f = 0{,}0035 + \frac{0{,}264}{(6.9094{,}7417)^{0{,}42}}$ $f = 0{,}0059$ 5. $\Delta F_p = \frac{4 \times f \times Gp^2 \times L}{2 \times g \times \rho^2 \times D_e}$ Pers 6.14 DQ Kern $g = 4{,}18 \times 10^8 \text{ft/hr}^2$ $\rho = 62{,}4300 \text{ lb/ft}^3$ $\Delta F_p = \frac{4 \times 0{,}0059 \times (25.910{,}5281 \text{ lb/hr ft})^2 \times 72 \text{ ft}}{2 \times 4{,}18 \times 10^8 \text{ft/hr} \times (62{,}4300 \text{ lb/ft}^3)^2 \times 0{,}1723 \text{ ft}}$ $\Delta F_p = 0{,}0438 \text{ ft}$ 6. $\Delta P_p = \frac{(\Delta F_p)\rho}{144}$ Pers 3.45 DQ Kern $\Delta P_a = \frac{(0{,}0438 \text{ ft}) \; 62{,}4300 \text{ lb/ft}^3}{144}$ $\Delta P_a = 0{,}0190$ psi ΔP_a yang diizinkan=10 psi 0,0190 psi < 10 psi (Memenuhi)

$\Delta F_l = \dfrac{V^2}{2g}$ $\Delta F_l = \dfrac{(1{,}0989\ ft/s)^2}{2 \times 32{,}2\ ft/s^2}$ $\Delta F_l = 0{,}0188\ ft$ 4. $\Delta P_a = \frac{(\Delta Fa + \Delta F1)\rho}{144}$ Pers 3.45 DQ Kern $\Delta P_a = \dfrac{(1{,}0050\ ft + 0{,}0188\ ft)\ 62{,}9029\ lb/ft^3}{144}$ $\Delta P_a = 0{,}4472$ psi ΔP_a yang diizinkan=10 psi 0,4472 psi < 10 psi (Memenuhi)	

16) *Decanter* (D-3151)

Fungsi	: Tempat untuk memisahkan triolein dari sabun cair
Tipe	: *Continous gravity decanter*
Bahan konstruksi	: *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*
Jumlah	: 1 unit
Sifat bahan	: Tidak volatil dan korosif pada baja ringan
Fasa	: Cair



Gambar LC-19. *Decanter*

Data:

- Laju alir umpan : 2.313,8652 kg/jam : 2,2993 lb/jam
- *Light phase* : Triolein (Fase terdispersi)
  Laju alir volumetrik : 0,1346 m^3/jam
  Densitas : 866,8611 kg/m^3
  Viskositas : 6,5925 cP
- *Heavy phase* : Sabun cair (Fase *continue*)
  Laju alir volumetrik : 2,1647 m^3/jam
  Densitas : 1.015,0453 kg/m^3
  Viskositas : 1,3444 cP
- Tekanan : 1 atm

1. Penentuan fase terdispersi

$$\psi = \frac{Q_L}{Q_H} \times \left(\frac{\rho_L \times u_H}{\rho_H \times u_L}\right)^{0,3}$$ Walas Pers 18.5

Dengan ketentuan

Jika ψ < 0,3	*light phase* selalu terdispersi
Jika ψ < 0,3-0,5	*light phase* mungkin tersebar
Jika ψ < 0,5-2,0	kemungkinan inversi fase, desain untuk kasus terburuk
Jika ψ < 2,0-3,3	*heavy phase* mungkin terdispersi
Jika ψ < 3,3	*heavy phase* selalu terdispersi

$$\psi = \frac{0,1346\ m^3/jam}{2,1647\ m^3/jam} \times \left(\frac{866,8611\ kg/m^3 \times 1,3444\ cP}{1.015,0453\ kg/m^3 \times 6,5925\ cP}\right)^{0,3} = 0,0368$$

2. Menentukan kecepatan pemisahan

$$U_d = \frac{d_d^2 g(\rho_L - \rho_H)}{18\mu_c}$$ Couldson Richardson Halaman 442

U_d / *droplet diameter* 0,00015 m

$$U_d = \frac{(0{,}00015\text{m})^2 \times 9{,}81\ \text{m/s}(866{,}8611\ \text{kg/m}^3 - 1.015{,}0453)}{18 \times 0{,}0013\ \text{N.s/m}^2}$$

$U_d = -1{,}3978 \times 10^{-3}$ m/s

Nilai kecepatan pemisahan (u_d) bernilai negatif karena butiran yang terdispersi bergerak berlawanan dengan arah gravitasi (ke atas), ini berarti $U_c < U_d$ maka nilai U_c maksimal = U_d

Continuous phase volumetric flow rate

$$L_c = \frac{U_c}{U_d}$$ Couldson Richardson Halaman 442

$$L_c = \frac{2{,}1647\ \text{m}^3/\text{jam}}{0{,}1346\ \text{m}^3/\text{jam}} \times \frac{1\ \text{jam}}{3600\ \text{s}} = 4 \times 10^{-3}\ \text{m}^3/\text{s}$$

3. Menentukan waktu pemisahan

$$t = \frac{100\ \mu_H}{\rho_H - \rho_L}$$ Mc.cabe pers 2.15

$$t = \frac{100 \times 1{,}3444\ \text{cP}}{1.015{,}0453\ \text{kg/m}^3 - 866{,}8611\ \text{kg/m}^3} = 0{,}9072\ \text{jam}$$

= 54,4320 menit

= 3.265,9200 sekon

4. Menentukan panjang dan diameter

Area of interface

$$A_i = \frac{L_c}{U_d}$$ Couldson Richardson Halaman 442

$$A_i = \frac{4 \times 10^{-3}\ \text{m}^3/\text{s}}{1{,}3978 \times 10^{-3}\ \text{m/s}} = 2{,}8616\ \text{m}^2$$

Vessel radius "r" is as putting value of interfacial area we get

$$r = \sqrt{\frac{A_i}{\pi}}$$ Couldson Richardson Halaman 442

$$r = \sqrt{\frac{2{,}8616\ m^2}{3{,}14}} = 0{,}9546\ m$$

D = 2×0,9546 m = 1,9092 m

Diambil L/D = 3

L = 3×1,9092 m = 5,7276 m

5. *Liquid Hold Up Volume*

Liquid hold up volume = t × L_c

Liquid hold up volume = 0,9072 jam × 2,1647 m^3/ jam = 1,9638 m^3

Jika tanpa piringan kiri dan kanan, maka volume dari tangki adalah 95%

Volume of vessel = 1,9638 m^3/0,95 = 2,0672 m^3

Fraksi volume tangki yang ditempati oleh cairan akan menjadi 95%, dan untuk silinder horizontal ini berarti cairan akan menjadi 90% dari diameter.

Z_T = 0,9 × 1,9092 m^3 = 1,7183 m   Mc.cabe halaman 37

Liquid interface adalah 50% dari diameter tangki.

Z_{A1} = 0,5 × 1,9092 m^3 = 0,9546 m   Mc.cabe halaman 37

Z_B = Z_{A1} - Z_T = 0,7637 m   Mc.cabe halaman 37

Height from datum to heavy liquid overflow

$$Z_{A2} = Z_{A1} + \frac{Z_T}{Z_{A1}} \times \frac{\rho_H}{\rho_L}$$ Mc.cabe halaman 37

$$Z_{A2} = 0{,}9546\ m + \frac{1{,}7183\ m}{0{,}9546\ m} \times \frac{866{,}8611\ kg/m^3}{1.015{,}0453\ kg/m^3} = 1{,}6068\ m$$

6. Menghitung Dimensi Tangki

Kapasitas *Decanter*

V_p = 2,0672 m^3

Dengan Mempertimbangkan faktor keamanan 20 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

V_p = 0,85 V_t

$$V_t = \frac{V_p}{0,85}$$

$$V_t = \frac{2,0672\ m^3}{0,80}$$

V_t = 2,5840 m^3

Diameter Tangki

D_t = 1,9092 m

Panjang Tangki

L_s = 5,7276 m

Panjang *ellipsoidal*

L_e = 0,25 D_t

L_e = 0,25 × 1,9092 m = 0,4773 m

Panjang Total *Decanter*

$L_t = L_s + (2\ L_e)$

L_t = 5,727 m + (2 × 0,4773 m)

L_t = 6,6822 m

P_d = 14,7 psi

R = 37,5826 in

S = 18700 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

Tebal Dinding *Decanter*

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{14,7 \text{ psi} \times 37,5826 \text{ in}}{18700 \text{ psi} \times 0,85 - 0,6 \times 14,7 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2348 in

= 0,0060 m

= 0,0197 ft

= 5,9639 mm

Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0,2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{14,7 \text{ psi} \times 75,1652 \text{ in}}{2 \times 18700 \text{ psi} \times 0,85 - 0,2 \times 14,7 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2348 in

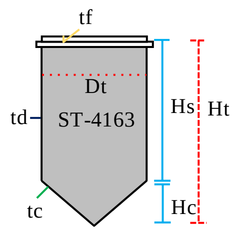
= 0,0060 m

= 0,0197 ft

= 5,9639 mm

17) *Storage Tank Ethylene Diamine Tetra Acetic Acid* (ST-4163)

Fungsi	: Tempat menyimpan *ethylene diamine tetra acetic acid*
Tipe	: Silinder vertikal dengan alas *conical* dan tutup datar
Bahan konstruksi	: *Carbon steel 70 C-Si (SA-515 Grade 70)*
Jumlah	: 1 unit
Sifat bahan	: Tidak volatil, tidak higroskopis dan tidak korosif
Fasa	: Padat



Gambar LC-20. *Storage Tank EDTA*

Data:

• Laju alir umpan	: 4,3944 kg/jam	: 9,6879 lb/jam
• Densitas campuran	: 861,4 kg/m^3	: 53,7772 lb/ft^3
• Tekanan	: 1 atm	
• Viskositas Campuran	: 19,8090 cP	: 0,0133 lb/ft.s
• Lama Penyimpanan	: 7 Hari	: 168 jam

1. Kapasitas Tangki

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

$$V_p = \frac{4{,}3944 \text{ kg/jam} \times 168 \text{ jam}}{861{,}4 \text{ kg/m}^3}$$

V_p = 0,8570 m^3

= 30,2641 ft^3

= 52.297,3486 in^3

= 226,3954 gal

Dengan Mempertimbangkan faktor keamanan 15 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

V_p = 0,85 V_t

$$V_t = \frac{V_p}{0{,}85}$$

$$V_t = \frac{0{,}8570 \text{ m}^3}{0{,}85}$$

V_t = 1,0082 m^3

= 35,6063 ft^3

= 61.524,1387 in^3

= 266,3382 gal

2. Dimensi Tangki

a. Volume Silinder

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

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

V_s = 1,1775 D_t^3

b. Volume *Conical*

$V_c = \frac{\pi}{6} \times D_t^2 \times H_c$ Dengan $H_c = 1/2\ D_t \tan 45°$ (*Table 18.4, Chemical Process Equipment*, S. Walas, Page 658)

$V_c = 0{,}2617\ D_t^3$

c. Diameter Tangki

$V_t = V_s + V_c$

$V_t = 1{,}1775\ D_t^3 + 0{,}2617\ D_t^3$

$V_t = 1{,}4392\ D_t^3$

$D_t^3 = \frac{V_t}{1{,}4392}$

$D_t^3 = \frac{1{,}0082\ m^3}{1{,}4392}$

$D_t = \sqrt[3]{\frac{1{,}0082\ m^3}{1{,}4392}}$

$D_t = 0{,}8882$ m

= 2,9133 ft

= 34,9684 in

d. Tinggi Silinder

$H_s = 1{,}5\ D_t$

$H_s = 1{,}5 \times 0{,}8882$ m

$H_s = 1{,}3323$ m

= 4,3699 ft

= 52,4527 in

e. Tinggi *Conical*

$H_c = 1/2\ D_t \tan 45°$

H_c = 1/2 × 0,8882 m × 1

H_c = 0,4441 m

= 1,4566 ft

= 17,4862 in

f. Tinggi Tangki

$H_t = H_s + H_c$

H_t = 1,3323 m + 0,4441 m

H_t = 1,7764 m

P_d = 14,7 psi

R = 17,4842 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

g. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{14,7 \text{ psi} \times 17,4842 \text{ in}}{17500 \text{ psi} \times 0,85 - 0,6 \times 14,7 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2173 in

= 0,0055 m

= 0,0180 ft

= 5,5194 mm

h. Tebal Dinding *Conical*

$t_c = \frac{PD}{2(SE - 0,2P)\cos 30°} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_c = \frac{14,7 \text{ psi} \times 34,9684 \text{ in}}{2(17500 \text{ psi} \times 0,85 - 0,2 \times 14,7 \text{ psi})0,71} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_c = 0,2243 in

= 0,0057 m

= 0,0187 ft

= 5,6972 mm

i. Tebal Tutup Tangki

$t_f = D\sqrt{\frac{0,3 P}{S}} + C$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$t_f = 34,9684 \text{ in}\sqrt{\frac{0,3 \times 14,7 \text{ psi}}{17500 \text{ psi}}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$ = 0,7551 in

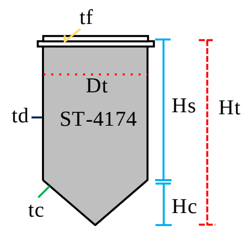
= 0,0192 m

= 0,0630 ft

= 19,1795 mm

18) *Storage Tank Triclocarban* (ST-4174)

Fungsi	: Tempat menyimpan *triclocarban*
Tipe	: Silinder vertikal dengan alas *conical* dan tutup datar
Bahan konstruksi	: *Carbon steel 70 C-Si (SA-515 Grade 70)*
Jumlah	: 1 unit
Sifat bahan	: Tidak volatil, tidak higroskopis dan tidak korosif
Fasa	: Padat



Gambar LC-21. *Storage Tank Triclocarban*

Data:

- Laju alir umpan : 21,9722 kg/jam : 48,4399 lb/jam
- Densitas campuran : 1.917,28 kg/m^3 : 119,6958 lb/ft^3
- Tekanan : 1 atm
- Viskositas Campuran : 23,44 cP : 0,0158 lb/ft.s
- Lama Penyimpanan : 7 Hari : 168 jam

1. Kapasitas Tangki

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

$$V_p = \frac{21{,}9722 \text{ kg/jam} \times 168 \text{ jam}}{1.917{,}28 \text{ kg/m}^3}$$

$$V_p = 1{,}9253 \text{ m}^3$$

$$= 67{,}9900 \text{ ft}^3$$

$$= 117.489{,}0143 \text{ in}^3$$

$= 508{,}6104$ gal

Dengan Mempertimbangkan faktor keamanan 10 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$V_p = 0{,}90\ V_t$

$$V_t = \frac{V_p}{0{,}90}$$

$$V_t = \frac{1{,}9253\ m^3}{0{,}90}$$

$V_t = 2{,}1392\ m^3$

$= 75{,}5437\ ft^3$

$= 130.541{,}9932\ in^3$

$= 565{,}1167$ gal

2. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1{,}1775\ D_t^3$

b. Volume *Conical*

$$V_c = \frac{\pi}{6} \times D_t^2 \times H_c \qquad \text{Dengan } H_c = 1/2\ D_t \tan 45°$$

(*Table 18.4, Chemical Process Equipment*, S. Walas, Page 658)

$V_c = 0{,}2617\ D_t^3$

c. Diameter Tangki

$V_t = V_s + V_c$

$V_t = 1{,}1775\ D_t^3 + 0{,}2617\ D_t^3$

$V_t = 1{,}4392\ D_t^3$

$D_t^3 = \dfrac{V_t}{1{,}4392}$

$D_t^3 = \dfrac{2{,}1392\ m^3}{1{,}4392}$

$D_t = \sqrt[3]{\dfrac{2{,}1392\ m^3}{1{,}4392}}$

$D_t = 1{,}1411$ m

= 3,7428 ft

= 44,9251 in

d. Tinggi Silinder

$H_s = 1{,}5\ D_t$

$H_s = 1{,}5 \times 1{,}1411$ m

$H_s = 1{,}7117$ m

= 5,6144 ft

= 67,3896 in

e. Tinggi *Conical*

$H_c = 1/2\ D_t \tan 45°$

$H_c = 1/2 \times 1{,}1411\ m \times 1$

$H_c = 0{,}5706$ m

= 1,8716 ft

= 22,4645 in

f. Tinggi Tangki

$H_t = H_s + H_c$

$H_t = 1{,}7117\ m + 0{,}5706$ m

H_t = 2,2823 m

P_d = 14,7 psi

R = 22,4626 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

g. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{14,7 \text{ psi} \times 22,4626 \text{ in}}{17500 \text{ psi} \times 0,85 - 0,6 \times 14,7 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2222 in

= 0,0056 m

= 0,0184 ft

= 5,6439 mm

h. Tebal Dinding *Conical*

$$t_c = \frac{PD}{2(SE - 0{,}2P)\cos 30°} + C$$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_c = \frac{14{,}7 \text{ psi} \times 44{,}9251 \text{ in}}{2(17500 \text{ psi} \times 0{,}85 - 0{,}2 \times 14{,}7 \text{ psi})0{,}71} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_c = 0,2313 in

= 0,0059 m

= 0,0194 ft

= 5,8750 mm

i. Tebal Tutup Tangki

$$t_f = D\sqrt{\frac{0{,}3\ P}{S}} + C$$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$$t_f = 44{,}9251 \text{ in}\sqrt{\frac{0{,}3 \times 14{,}7 \text{ psi}}{17500 \text{ psi}}} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun} = 0{,}9132 \text{ in}$$

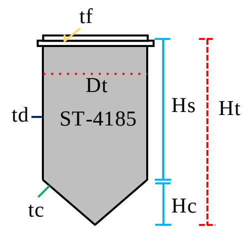
= 0,0232 m

= 0,0761 ft

= 23,1953 mm

19) *Storage Tank Sunset Yellow FCF* (ST-4185)

Fungsi	: Tempat menyimpan *sunset yellow FCF*
Tipe	: Silinder vertikal dengan alas *conical* dan tutup datar
Bahan konstruksi	: *Carbon steel 70 C-Si (SA-515 Grade 70)*
Jumlah	: 1 unit
Sifat bahan	: Tidak volatil, tidak higroskopis dan tidak korosif
Fasa	: Padat



Gambar LC-22. *Storage Tank Sunset Yellow FCF*

Data:

- Laju alir umpan : 21,9722 kg/jam : 48,4399 lb/jam
- Densitas campuran : 800 kg/m^3 : 49,9440 lb/ft^3
- Tekanan : 1 atm
- Viskositas Campuran : 28,9 cP : 0,0194 lb/ft.s
- Lama Penyimpanan : 7 Hari : 168 jam

1. Kapasitas Tangki

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

$$V_p = \frac{21,9722 \text{ kg/jam} \times 168 \text{ jam}}{800 \text{ kg/m}^3}$$

V_p = 4,6142 m^3

= 162,9459 ft^3

= 281.575,7596 in^3

= 1.218,9424 gal

Dengan Mempertimbangkan faktor keamanan 10 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

V_p = 0,90 V_t

$$V_t = \frac{V_p}{0,90}$$

$$V_t = \frac{4{,}6142\ m^3}{0{,}90}$$

V_t = 5,1269 m^3

= 181,0513 ft^3

= 312.862,6331 in^3

= 1.354,3834 gal

2. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1{,}1775\ D_t^3$

b. Volume *Conical*

$V_c = \frac{\pi}{6} \times D_t^2 \times H_c$ Dengan $H_c = 1/2\ D_t \tan 45°$ (*Table 18.4, Chemical Process Equipment*, S. Walas, Page 658)

$V_c = 0{,}2617\ D_t^3$

c. Diameter Tangki

$V_t = V_s + V_c$

$V_t = 1{,}1775\ D_t^3 + 0{,}2617\ D_t^3$

$V_t = 1{,}4392\ D_t^3$

$$D_t^3 = \frac{V_t}{1{,}4392}$$

$$D_t^3 = \frac{5{,}1269\ m^3}{1{,}4392}$$

$$D_t = \sqrt[3]{\frac{5,1269\ m^3}{1,4392}}$$

D_t = 1,5266 m

= 5,0072 ft

= 60,1022 in

d. Tinggi Silinder

$H_s = 1,5\ D_t$

$H_s = 1,5 \times 1,5266$ m

H_s = 2,2899 m

= 7,5109 ft

= 90,1534 in

e. Tinggi *Conical*

$H_c = 1/2\ D_t \tan 45°$

$H_c = 1/2 \times 1,5266\ m \times 1$

H_c = 0,7633 m

= 2,5036 ft

= 30,0511 in

f. Tinggi Tangki

$H_t = H_s + H_c$

H_t = 2,2899 m + 0,7633 m

H_t = 3,0532 m

P_d = 14,7 psi

R = 30,0511 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

g. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{14,7 \text{ psi} \times 30,0511 \text{ in}}{17500 \text{ psi} \times 0,85 - 0,6 \times 14,7 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2297 in

= 0,0058 m

= 0,0190 ft

= 5,8344 mm

h. Tebal Dinding *Conical*

$t_c = \frac{PD}{2(SE - 0,2P)\cos 30°} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_c = \frac{14,7 \text{ psi} \times 60,1022 \text{ in}}{2(17500 \text{ psi} \times 0,85 - 0,2 \times 14,7 \text{ psi})0,71} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_c = 0,2418 in

= 0,0061 m

= 0,0200 ft

= 6,1471 mm

i. Tebal Tutup Tangki

$$t_f = D\sqrt{\frac{0{,}3\ P}{S}} + C$$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$$t_f = 60{,}1022\ \text{in}\sqrt{\frac{0{,}3 \times 14{,}7\ \text{psi}}{17500\ \text{psi}}} + 0{,}02\ \text{in/tahun} \times 10\ \text{tahun} = 1{,}1541\ \text{in}$$

= 0,0293 m

= 0,0961 ft

= 29,3141 mm

20) *Storage Tank Glycerol* (ST-4196)

Fungsi : Tempat menyimpan gliserol

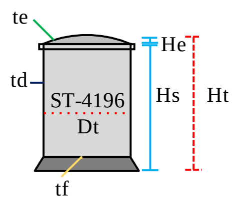
Tipe : Silinder vertikal dengan alas datar dan tutup *elipsoidal*

Bahan konstruksi : *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*

Jumlah : 1 unit

Sifat bahan : Tidak volatil, korosif dan tidak higroskopis

Fasa : Cair



Gambar LC-23. *Storage Tank Glycerol*

Data:

- Laju alir umpan : 219,7221 kg/jam : 484,3993 lb/jam
- Densitas campuran : 1.258,7000 kg/m^3 : 78,5806 lb/ft^3
- Tekanan : 1 atm
- Viskositas Campuran : 16,9195 cP : 0,0114 lb/ft.s
- Lama Penyimpanan : 7 hari : 168 jam

1. Kapasitas Tangki

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

$$V_p = \frac{219{,}7221 \text{ kg/jam} \times 168 \text{ jam}}{1.258{,}7000 \text{ kg/m}^3}$$

$$V_p = 29{,}3265 \text{ m}^3$$

$$= 1.035{,}6360 \text{ ft}^3$$

$$= 1.789.612{,}8284 \text{ in}^3$$

$$= 7.747{,}2402 \text{ gal}$$

Dengan Mempertimbangkan faktor keamanan 10 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$$V_p = 0{,}9\ V_t$$

$$V_t = \frac{V_p}{0{,}9}$$

$$V_t = \frac{29{,}3265 \text{ m}^3}{0{,}9}$$

$$V_t = 32{,}5850 \text{ m}^3$$

$$= 1.150{,}7067 \text{ ft}^3$$

$$= 1.988.458{,}6982 \text{ in}^3$$

$$= 8.608{,}0446 \text{ gal}$$

2. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1{,}1775\ D_t^3$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4, Chemical Process Equipment,* S. Walas, Page 658)

$V_e = 0{,}1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + V_e$

$V_t = 1{,}1775\ D_t^3 + (0{,}1308\ D_t^3)$

$V_t = 1{,}3083\ D_t^3$

$D_t^3 = \frac{V_t}{1{,}3083}$

$D_t^3 = \frac{32{,}5850\ m^3}{1{,}3083}$

$D_t = \sqrt[3]{\frac{32{,}5850\ m^3}{1{,}3083}}$

$D_t = 2{,}9172$ m

= 9,5684 ft

= 114,8502 in

d. Tinggi Silinder

$H_s = 1{,}5\ D_t$

$H_s = 1{,}5 \times 2{,}9172$ m

$H_s = 4{,}3758$ m

$= 14{,}3526$ ft

$= 172{,}2752$ in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 2{,}9172$ m

$H_e = 0{,}7293$ m

$= 2{,}3921$ ft

$= 28{,}7125$ in

f. Tinggi Tangki

$H_t = H_s + H_e$

$H_t = 4{,}3758\text{ m} + 0{,}7293\text{ m}$

$H_t = 5{,}1051$ m

g. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s + (H_e))}{V_t}$$

$$H_c = \frac{29{,}3265\text{ m}^3 \times (4{,}3758\text{ m} + (0{,}7293\text{ m}))}{32{,}5850\text{ m}^3}$$

$H_c = 4{,}5946$ m

$= 15{,}0703$ ft

$= 180{,}8894$ in

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

P_c = 1.258,7000 kg/m^3× 9,81 m/s^2 × 4,5946 m

P_c = 56.733,4178 kg.m/s^2

= 0,5503 atm

= 8,0872 psi

i. Tekanan Desain

P_d = P_{op}+ P_c

P_d = 1 atm + 0,5503 atm

P_d = 1,5503 atm

= 22,7831 psi

P_d = 22,7831 psi

R = 57,4251 in

S = 18700 psi (*Peters* - *Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{22,7831 \text{ psi} \times 57,4251 \text{ in}}{18700 \text{ psi} \times 0,85 - 0,6 \times 22,7831 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2824 in

= 0,0072 m

= 0,0236 ft

= 7,1730 mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0,2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{22,7831 \text{ psi} \times 114,8502 \text{ in}}{2 \times 18700 \text{ psi} \times 0,85 - 0,2 \times 22,7831 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2823 in

= 0,0072 m

= 0,0236 ft

= 7,1704 mm

l. Tebal Alas Tangki

$t_f = D\sqrt{\frac{0,3 P}{S}} + C$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$$t_f = 114,8502 \text{ in}\sqrt{\frac{0,3 \times 22,7831 \text{ psi}}{18700 \text{ psi}}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun} = 2,3957 \text{ in}$$

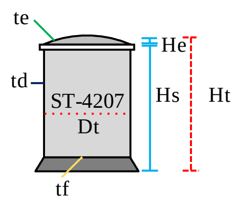
= 0,0690 m

= 0,1998 ft

= 60,8508 mm

21) *Storage Tank Cocoamidopropyl Betaine* (ST-4207)

Fungsi	: Tempat menyimpan *cocoamidopropyl betaine*
Tipe	: Silinder vertikal dengan alas datar dan tutup *elipsoidal*
Bahan konstruksi	: *Carbon steel 70 C-Si (SA-515 Grade 70)*
Jumlah	: 1 unit
Sifat bahan	: Tidak volatil, tidak korosif dan tidak higroskopis
Fasa	: Cair



Gambar LC-24. *Storage Tank Cocoamidopropyl Betaine*

Data:

• Laju alir umpan	: 54,9305 kg/jam	: 121,0998 lb/jam
• Densitas campuran	: 1.014,0000 kg/m^3	: 63,3040 lb/ft^3
• Tekanan	: 1 atm	
• Viskositas Campuran	: 5,8 cP	: 0,0039 lb/ft.s
• Lama Penyimpanan	: 7 hari	: 168 jam

1. Kapasitas Tangki

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

$$V_p = \frac{54{,}9305 \text{ kg/jam} \times 168 \text{ jam}}{1.014{,}0000 \text{ kg/m}^3}$$

$$V_p = 9{,}1009 \text{ m}^3$$

$$= 321{,}3892 \text{ ft}^3$$

$$= 555.370{,}9918 \text{ in}^3$$

$$= 2.404{,}2030 \text{ gal}$$

Dengan Mempertimbangkan faktor keamanan 10 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$V_p = 0{,}9\ V_t$

$$V_t = \frac{V_p}{0{,}9}$$

$$V_t = \frac{9{,}1009\ m^3}{0{,}9}$$

$V_t = 10{,}1121\ m^3$

$= 357{,}0987\ ft^3$

$= 617.078{,}2017\ in^3$

$= 2.671{,}3337$ gal

2. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1{,}1775\ D_t^3$

b. Volume *Ellipsoidal*

$$V_e = \frac{\pi}{6} \times D_t^2 \times H_e \qquad \text{Dengan } H_e = 1/4\ D_t$$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0{,}1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + V_e$

$V_t = 1{,}1775\ D_t^3 + (0{,}1308\ D_t^3)$

$V_t = 1{,}3083\ D_t^3$

$D_t^3 = \frac{V_t}{1,3083}$

$D_t^3 = \frac{10,1121\ m^3}{1,3083}$

$D_t = \sqrt[3]{\frac{10,1121\ m^3}{1,3083}}$

$D_t = 1,9758$ m

= 6,4806 ft

= 77,7872 in

d. Tinggi Silinder

$H_s = 1,5\ D_t$

$H_s = 1,5 \times 1,9758$ m

$H_s = 2,9637$ m

= 9,7209 ft

= 116,6809 in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 1,9758$ m

$H_e = 0,4940$ m

= 1,6203 ft

= 19,4488 in

f. Tinggi Tangki

$H_t = H_s + H_e$

$H_t = 2,9637$ m + 0,4940 m

$H_t = 3,4577$ m

g. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s + (H_e))}{V_t}$$

$$H_c = \frac{9{,}1009\ m^3 \times (2{,}9637\ m + (0{,}4940\ m))}{10{,}1121\ m^3}$$

H_c = 3,1119 m

= 10,2070 ft

= 122,5155 in

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

P_c = 1.014,0000 kg/m^3× 9,81 m/s^2 × 3,1119 m

P_c = 30.955,1273 kg.m/s^2

= 0,3003 atm

= 4,4132 psi

i. Tekanan Desain

$P_d = P_{op} + P_c$

P_d = 1 atm + 0,3003 atm

P_d = 1,3003 atm

= 19,1091 psi

P_d = 19,1091 psi

R = 38,8936 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{19,1091 \text{ psi} \times 38,8936 \text{ in}}{17500 \text{ psi} \times 0,85 - 0,6 \times 19,1091 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2500 in

= 0,0064 m

= 0,0210 ft

= 6,3500 mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0,2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{19,1091 \text{ psi} \times 77,7872 \text{ in}}{2 \times 17500 \text{ psi} \times 0,85 - 0,2 \times 19,1091 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2500 in

= 0,0064 m

= 0,0210 ft

$= 6{,}3500$ mm

l. Tebal Alas Tangki

$$t_f = D\sqrt{\frac{0{,}3\ P}{S}} + C$$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$$t_f = 77{,}7872\ in\sqrt{\frac{0{,}3 \times 19{,}1091\ psi}{17500\ psi}} + 0{,}02\ in/tahun \times 10\ tahun = 1{,}6079\ in$$

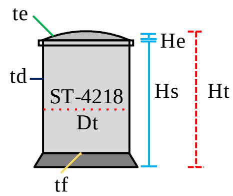
$= 0{,}0408$ m

$= 0{,}1338$ ft

$= 40{,}8407$ mm

22) *Storage Tank* Minyak Kayu Manis (ST-4218)

Fungsi	: Tempat menyimpan minyak kayu manis
Tipe	: Silinder vertikal dengan alas datar dan tutup *elipsoidal*
Bahan konstruksi	: *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*
Jumlah	: 1 unit
Sifat bahan	: Volatil, korosif dan higroskopis
Fasa	: Cair



Gambar LC-25. *Storage Tank* Minyak Kayu Manis

Data:

• Laju alir umpan	: 5,0404 kg/jam	: 11,1121 lb/jam
• Densitas campuran	: 1.048,0000 kg/m^3	: 65,4266 lb/ft^3
• Tekanan	: 1 atm	
• Viskositas Campuran	: 1,02 cP	: 0,0007 lb/ft.s

- Lama Penyimpanan : 3 hari : 72 jam

1. Kapasitas Tangki

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

$$V_p = \frac{11{,}1121 \text{ kg/jam} \times 72 \text{ jam}}{1.048{,}0000 \text{ kg/m}^3}$$

V_p = 0,3463 m^3

= 12,2292 ft^3

= 21.132,5225 in^3

= 91,4828 gal

Dengan Mempertimbangkan faktor keamanan 15 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

V_p = 0,85 V_t

$$V_t = \frac{V_p}{0{,}85}$$

$$V_t = \frac{0{,}3463 \text{ m}^3}{0{,}85}$$

V_t = 0,3848 m^3

= 13,5888 ft^3

= 23.481,9367 in^3

= 101,6534 gal

2. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1,1775\ D_t^3$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0,1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + V_e$

$V_t = 1,1775\ D_t^3 + (0,1308\ D_t^3)$

$V_t = 1,3083\ D_t^3$

$D_t^3 = \frac{V_t}{1,3083}$

$D_t^3 = \frac{0,3848\ m^3}{1,3083}$

$D_t = \sqrt[3]{\frac{0,3848\ m^3}{1,3083}}$

$D_t = 0,6653$ m

= 2,1822 ft

= 26,1929 in

d. Tinggi Silinder

$H_s = 1,5\ D_t$

$H_s = 1,5 \times 0,6653$ m

$H_s = 0,9980$ m

= 3,2734 ft

= 39,2913 in

e. Tinggi *Ellipsoidal*

H_e = 1/4 D_t

H_e = 1/4 × 0,6653 m

H_e = 0,1663 m

= 0,5455 ft

= 6,5472 in

f. Tinggi Tangki

$H_t = H_s + H_e$

H_t = 0,9980 m + 0,1663 m

H_t = 1,1643 m

g. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s + (H_e))}{V_t}$$

$$H_c = \frac{0{,}3463 \text{ m}^3 \times (0{,}9980 \text{ m} + (0{,}1663 \text{ m}))}{0{,}3848 \text{ m}^3}$$

H_c = 1,0478 m

= 3,4368 ft

= 41,2519 in

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

P_c = 1.048,0000 kg/m^3 × 9,81 m/s^2 × 1,0478 m

P_c = 10.772,3061 kg.m/s^2

= 0,1045 atm

= 1,5357 psi

i. Tekanan Desain

$P_d = P_{op} + P_c$

P_d = 1 atm + 0,1045 atm

P_d = 1,1045 atm

= 16,2316 psi

P_d = 16,2316 psi

R = 13,0965 in

S = 18700 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{16,2316 \text{ psi} \times 13,0965 \text{ in}}{18700 \text{ psi} \times 0,85 - 0,6 \times 16,2316 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2134 in

= 0,0054 m

$= 0{,}0177$ ft

$= 5{,}4204$ mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0{,}2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{16{,}2316 \text{ psi} \times 26{,}1929 \text{ in}}{2 \times 18700 \text{ psi} \times 0{,}85 - 0{,}2 \times 16{,}2316 \text{ psi}} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun}$$

$t_e = 0{,}2134$ in

$= 0{,}0054$ m

$= 0{,}0177$ ft

$= 5{,}4204$ mm

l. Tebal Alas Tangki

$$t_f = D\sqrt{\frac{0{,}3\ P}{S}} + C$$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$$t_f = 26{,}1929 \text{ in}\sqrt{\frac{0{,}3 \times 16{,}2316 \text{ psi}}{18700 \text{ psi}}} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun} = 0{,}6227 \text{ in}$$

$= 0{,}0158$ m

$= 0{,}0518$ ft

$= 15{,}8166$ mm

23) *Continous Flow Conveyor* (CFC-4182)

Fungsi : Mentransportasikan aditif padat ke *mixing tank* 2

Tipe	: *Apron conveyor with pan*
Bahan konstruksi	: *Carbon steel 70 C-8 Si (SA-515 Grade 70)*
Jumlah	: 2 unit
Sifat bahan	: Tidak volatil, tidak higroskopis dan tidak korosif
Fasa	: Padat

Gambar LC-26. *Continous Flow Conveyor*

Data:

- Laju alir umpan : 48,3388 kg/jam : 0,0537 ton/jam
- Tekanan : 1 atm
- Faktor Keamanan : 10%

1. Kapasitas Conveyor

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

$$W = \frac{0,0537 \text{ ton/jam}}{0,9} = 0,0597 \text{ ton/jam}$$

2. Ukuran Conveyor

Dengan kapasitas di atas, dipilih *continuos flow conveyor* dengan spesifikasi sebagai berikut (Perry's 7th Ed, Tabel 21-11 Hal 21-19).

Lebar Conveyor	: 18 in	: 1,5 ft
Panjang Conveyor	: 12 m	: 39,36 ft
Kecepatan (u)	: 10 ft/min	: 3,0488 m/min
Lebar *Pan*	: 18 in	: 1,5 ft

3. Daya Conveyor

$$HP = 0{,}001 \left[\left(\frac{L1}{30} + 5\right) u + \left(\frac{L2}{16} + 2L3\right) T\right]$$ Walas - Chemical Process Equipment, Pers 5.26

u : kecepatan = 10 ft/menit

T : kapasitas conveyor = 0,0597 ton/jam

L_1 : panjang total conveyor = 39,36 ft

Asumsi :

L_2 : jarak horizontal yang ditempuh = 10 m = 32,8 ft

L_3 : jarak vertikal yang ditempuh = 1,9 m = 6,56 ft

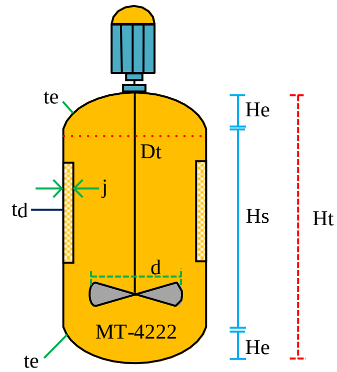
$$HP = 0{,}001 \left[\left(\frac{L1}{30} + 5\right) u + \left(\frac{L2}{16} + 2L3\right) T\right]$$

$$HP = 0{,}001 \left[\left(\frac{39{,}36 \text{ ft}}{30} + 5\right) 10 \text{ ft/min} + \left(\frac{32{,}8}{16} + 2 \times 1{,}9 \text{ ft}\right) 0{,}0597 \text{ ton/jam}\right]$$

$$HP = 0{,}0640 \approx 0{,}5$$

24) *Mixing Tank* 2 (MT-4222)

Fungsi	: Tempat melarutkan zat aditif dan sabun
Tipe	: Silinder vertikal dengan alas dan tutup *elipsoidal*
Bahan konstruksi	: *Carbon steel 70 C-Si (SA-515 Grade 70)*
Jumlah	: 1 unit
Sifat bahan	: Tidak volatil, tidak korosif dan tidak higroskopis
Fasa	: Cair



Gambar LC-27. *Mixing Tank* 2

Data:

- Laju alir umpan : 2.520,2122 kg/jam : 5.556,0598 lb/jam
- Densitas campuran : 1.039,7588 kg/m^3 : 64,9121 lb/ft^3
- Tekanan : 1 atm
- Viskositas Campuran : 3,2645 cP : 0,0022 lb/ft.s
- Waktu Pelarutan : 60 menit : 1 jam

1. Kapasitas Tangki

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

$$V_p = \frac{2.520,2122 \text{ kg/jam} \times 1 \text{ jam}}{1.039,7588 \text{ kg/m}^3}$$

V_p = 2,4238 m^3

= 85,5941 ft^3

= 147.909,3507 in^3

= 640,3001 gal

Dengan Mempertimbangkan faktor keamanan 20 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

V_p = 0,8 V_t

$$V_t = \frac{V_p}{0,8}$$

$$V_t = \frac{2,4238\ m^3}{0,8}$$

$V_t = 3,0298\ m^3$

$= 106.9944\ ft^3$

$= 184.889,7396\ in^3$

$= 800,3883$ gal

2. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1,1775\ D_t^3$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0,1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + 2\ V_e$

$V_t = 1,1775\ D_t^3 + 2\ (0,1308\ D_t^3)$

$V_t = 1,4391\ D_t^3$

$$D_t^3 = \frac{V_t}{1,4391}$$

$$D_t^3 = \frac{3{,}0298\ m^3}{1{,}4391}$$

$$D_t = \sqrt[3]{\frac{3{,}0298\ m^3}{1{,}4391}}$$

D_t = 1,2816 m

= 4,2036 ft

= 50,4566 in

d. Tinggi Silinder

$H_s = 1{,}5\ D_t$

$H_s = 1{,}5 \times 1{,}2816$ m

H_s = 1,9224 m

= 6,3055 ft

= 75,6849 in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 1{,}2816$ m

H_e = 0,3204 m

= 1,0509 ft

= 12,6141 in

f. Tinggi Tangki

$H_t = H_s + (2\ H_e)$

$H_t = 1{,}9224\ m + (2 \times 0{,}3204\ m)$

H_t = 2,5632 m

g. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s + (2\ H_e))}{V_t}$$

$$H_c = \frac{2{,}4238\ m^3 \times (1{,}9224\ m + (2 \times 0{,}3204\ m))}{3{,}0298\ m^3}$$

H_c = 2,0505 m

= 6,7256 ft

= 80,7282 in

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

P_c = 1.039,7588 kg/m^3× 9,81 m/s^2 × 2,0505 m

P_c = 20.915,1694 kg.m/s^2

= 0,2029 atm

= 2,9818 psi

i. Tekanan Desain

$P_d = P_{op} + P_c$

P_d = 1 atm + 0,2029 atm

P_d = 1,2029 atm

= 17,6826 psi

P_d = 17,6826 psi

R = 25,2283 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{17,6826 \text{ psi} \times 25,2283 \text{ in}}{17500 \text{ psi} \times 0,85 - 0,6 \times 17,6826 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2300 in

= 0,0058 m

= 0,0190 ft

= 5,8420 mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0,2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{17,6826 \text{ psi} \times 50,4566 \text{ in}}{2 \times 17500 \text{ psi} \times 0,85 - 0,2 \times 17,6826 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2300 in

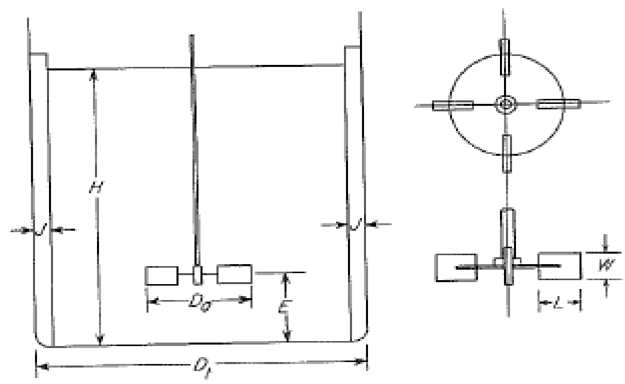
= 0,0058 m

= 0,0190 ft

= 5,8420 mm

3. Desain Pengaduk

Viskositas umpan < 4000 cP, maka dipilih *propeller* berdaun tiga (Kecepatan 1800 rpm) (*Walas - Selection Design & Chemical Process Equipment ed 1st, Page 288*).



Gambar LC-28. Desain Pengaduk *Mixing Tank* 2

a. Diameter Pengaduk

$$d = \frac{D_t}{3}$$

$$d = \frac{1{,}2816 \text{ m}}{3}$$

d = 0,4272 m

= 1,4012 ft

b. Panjang Daun Pengaduk

$$L = \frac{d}{4}$$

$$L = \frac{0{,}4272 \text{ m}}{4}$$

L = 0,1068 m

= 0,3503 ft

c. Lebar Daun Pengaduk

$$W = \frac{d}{5}$$

$$W = \frac{0,4272 \text{ m}}{5}$$

W = 0,0854 m

= 0,2801 ft

d. Tinggi Pengaduk Dari Dasar Tangki

$$E = \frac{D_t}{3}$$

$$E = \frac{1,2816 \text{ m}}{3}$$

E = 0,4272 m

= 1,4012 ft

e. Lebar *Baffle*

$$J = \frac{D_t}{12}$$

$$J = \frac{1,2816 \text{ m}}{12}$$

J = 0,1068 m

= 0,3503 ft

f. Kecepatan Putar Pengaduk

Berdasarkan persamaan 6-18 *Robert Treyball-Mass Transfer Operation,* kecepatan putar pengaduk dapat dihitung dengan persamaan berikut.

Dengan $g_c = 32,2 \text{ ft/s}^2$

σ = 72,75 dyn/cm (*Mc.cabe – Unit Operation Of Chemical Engineering 5th Page 274*).

$$= 0{,}0537 \text{ lb/ft}$$

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

$$\frac{N_d}{\left(\frac{0{,}0537 \text{ lb/ft} \times 32{,}2 \text{ ft/s}^2}{64{,}9121 \text{ lb/ft}^3}\right)^{0,25}} = 1{,}22 + 1{,}25 \left(\frac{4{,}2036 \text{ ft}}{1{,}4012 \text{ ft}}\right)$$

$$N_d = 1{,}9328 \text{ rps}$$

g. Daya Pengadukan

Berdasarkan persamaan 9-17 *Mc.cabe – Unit Operation Of Chemical Engineering 5^t*, bilangan *reynold* dapat dihitung dengan persamaan berikut.

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

$$N_{Re} = \frac{64{,}9121 \text{ lb/ft}^3 \times 1{,}9328 \text{ rps} \times (1{,}4012 \text{ ft})^2}{0{,}0022 \text{ lb/ft.s}}$$

N_{Re} = 111.967,0286

Karena Nre > 10.000, maka berdasarkan persamaan 9.24 *Mc.cabe – Unit Operation Of Chemical Engineering 5^t*, daya pengadukan menggunakan dapat dihitung dengan persamaan berikut.

Dengan K_T = 0,87 (*Mc. Cabe & Smith - Unit Operations Of Chemical Engineering 5th, Page 254*)

$$P = \frac{K_T N^3 D_a^5 \rho}{g_c}$$

$$P = \frac{0{,}87 \times (1{,}9328 \text{ rps})^3 \times (1{,}4012 \text{ ft})^5 \times 64{,}9121 \text{ lb/ft}^3}{32{,}2 \text{ ft/s}^2}$$

P = 68,3991 ft.lbf/s

P = 0,1244 HP

h. Daya Motor

Efisiensi Motor = 80%

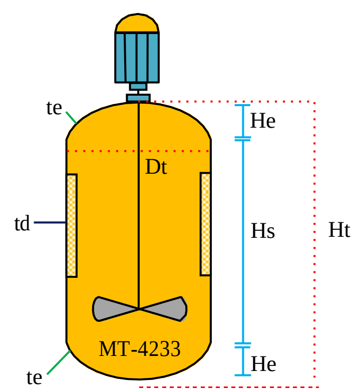
$$\text{Daya Motor} = \frac{0{,}1244\ \text{HP}}{80\%}$$

Daya Motor = 0,1555 HP

≈ 0,5 HP

25) *Mixing Tank* 3 (MT-4233)

Fungsi	: Tempat melarutkan pewangi dan sabun
Tipe	: Silinder vertikal dengan alas dan tutup *elipsoidal*
Bahan konstruksi	: *Carbon steel 70 C-Si (SA-515 Grade 70)*
Jumlah	: 1 unit
Sifat bahan	: Tidak volatil, tidak korosif dan tidak higroskopis
Fasa	: Cair



Gambar LC-29. *Mixing Tank* 3

Data:

• Laju alir umpan	: 2.525,2525 kg/jam	: 5.567,1728 lb/jam
• Densitas campuran	: 1.039,7732 kg/m^3	: 64,9130 lb/ft^3
• Tekanan	: 1 atm	
• Viskositas Campuran	: 3,2600 cP	: 0,0022 lb/ft.s

- Waktu Pelarutan : 30 menit : 0,5 jam

1. Kapasitas Tangki

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

$$V_p = \frac{2.525,2525 \text{ kg/jam} \times 0,5 \text{ jam}}{1.039,7732 \text{ kg/m}^3}$$

$V_p = 1,2143 \text{ m}^3$

$= 42,8818 \text{ ft}^3$

$= 74.101,1323 \text{ in}^3$

$= 320,7841 \text{ gal}$

Dengan Mempertimbangkan faktor keamanan 20 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$V_p = 0,8\ V_t$

$$V_t = \frac{V_p}{0,8}$$

$$V_t = \frac{1,2143 \text{ m}^3}{0,8}$$

$V_t = 1,5179 \text{ m}^3$

$= 53,6031 \text{ ft}^3$

$= 92.627,9410 \text{ in}^3$

$= 400,9867 \text{ gal}$

2. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1{,}1775\ D_t^3$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0{,}1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + 2\ V_e$

$V_t = 1{,}1775\ D_t^3 + 2\ (0{,}1308\ D_t^3)$

$V_t = 1{,}4391\ D_t^3$

$$D_t^3 = \frac{V_t}{1{,}4391}$$

$$D_t^3 = \frac{1{,}5179\ m^3}{1{,}4391}$$

$$D_t = \sqrt[3]{\frac{1{,}5179\ m^3}{1{,}4391}}$$

$D_t = 1{,}0179$ m

= 3,3387 ft

= 40,0747 in

d. Tinggi Silinder

$H_s = 1{,}5\ D_t$

$H_s = 1{,}5 \times 1{,}0179$ m

$H_s = 1{,}5629$ m

= 5,0082 ft

= 60,1141 in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 1{,}0179\ m$

$H_e = 0{,}2545\ m$

$= 0{,}8348\ ft$

$= 10{,}0197\ in$

f. Tinggi Tangki

$H_t = H_s + (2\ H_e)$

$H_t = 1{,}5629\ m + (2 \times 0{,}2545\ m)$

$H_t = 2{,}0359\ m$

g. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s + (2\ H_e))}{V_t}$$

$$H_c = \frac{1{,}2143\ m^3 \times (1{,}9224\ m + (2 \times 0{,}2545\ m))}{1{,}5179\ m^3}$$

$H_c = 1{,}4251\ m$

$= 4{,}6743\ ft$

$= 56{,}1062\ in$

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

$P_c = 1.039{,}7732\ kg/m^3 \times 9{,}81\ m/s^2 \times 1{,}4251\ m$

$P_c = 14.536{,}2695\ kg.m/s^2$

$= 0{,}1410\ atm$

$= 2{,}0721\ psi$

i. Tekanan Desain

$P_d = P_{op} + P_c$

P_d = 1 atm + 0,1410 atm

P_d = 1,1310 atm

= 16,7727 psi

P_d = 16,7727 psi

R = 20,0374 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{16,7727 \text{ psi} \times 20,0374 \text{ in}}{17500 \text{ psi} \times 0,85 - 0,6 \times 16,7727 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2226 in

= 0,0057 m

$= 0{,}0187$ ft

$= 5{,}6540$ mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0{,}2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{16{,}7727 \text{ psi} \times 40{,}0747 \text{ in}}{2 \times 17500 \text{ psi} \times 0{,}85 - 0{,}2 \times 16{,}7727 \text{ psi}} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun}$$

$t_e = 0{,}2226$ in

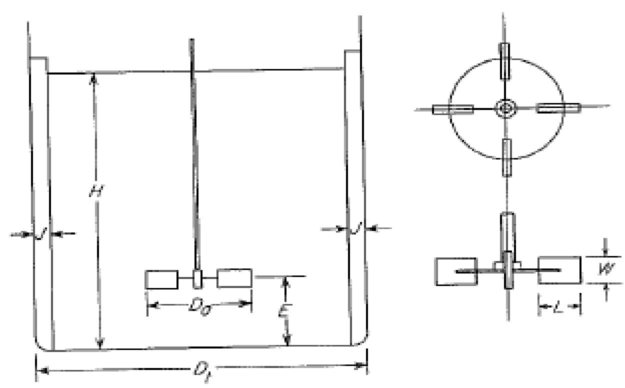
$= 0{,}0057$ m

$= 0{,}0187$ ft

$= 5{,}6540$ mm

3. Desain Pengaduk

Viskositas umpan < 4000 cP, maka dipilih *propeller* berdaun tiga (Kecepatan 1800 rpm) (*Walas - Selection Design & Chemical Process Equipment ed 1*st*, Page 288*).



Gambar LC-30. Desain Pengaduk *Mixing Tank* 3

a. Diameter Pengaduk

$$d = \frac{D_t}{3}$$

$$d = \frac{1,0179 \text{ m}}{3}$$

d = 0,3393 m

= 1,1129 ft

b. Panjang Daun Pengaduk

$$L = \frac{d}{4}$$

$$L = \frac{0,3393 \text{ m}}{4}$$

L = 0,0848 m

= 0,2781 ft

c. Lebar Daun Pengaduk

$$W = \frac{d}{5}$$

$$W = \frac{0,3393 \text{ m}}{5}$$

W = 0,0679 m

= 0,2227 ft

d. Tinggi Pengaduk Dari Dasar Tangki

$$E = \frac{D_t}{3}$$

$$E = \frac{1,0179 \text{ m}}{3}$$

E = 0,3393 m

= 1,1129 ft

e. Lebar *Baffle*

$$J = \frac{D_t}{12}$$

$$J = \frac{1,0179 \text{ m}}{12}$$

J = 0,0848 m

= 0,2781 ft

f. Kecepatan Putar Pengaduk

Berdasarkan persamaan 6-18 *Robert Treyball-Mass Transfer Operation,* kecepatan putar pengaduk dapat dihitung dengan persamaan berikut.

Dengan g_c = 32,2 ft/s^2

σ = 72,75 dyn/cm (*Mc.cabe – Unit Operation Of Chemical Engineering 5th Page 274*).

= 0,0537 lb/ft

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

$$\frac{N_d}{\left(\frac{0,0537 \text{ lb/ft} \times 32,2 \text{ ft/s}^2}{64,9130 \text{ lb/ft}^3}\right)^{0,25}} = 1,22 + 1,25 \left(\frac{3,3387 \text{ ft}}{1,1129 \text{ ft}}\right)$$

N_d = 2,4334 rps

g. Daya Pengadukan

Berdasarkan persamaan 9-17 *Mc.cabe – Unit Operation Of Chemical Engineering 5^t,* bilangan *reynold* dapat dihitung dengan persamaan berikut.

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

$$N_{Re} = \frac{64,9130 \text{ lb/ft}^3 \times 2,4334 \text{ rps} \times (1,1129 \text{ ft})^2}{0,0022 \text{ lb/ft.s}}$$

N_{Re} = 88.927,2349

Karena Nre > 10.000, maka berdasarkan persamaan 9.24 *Mc.cabe – Unit Operation Of Chemical Engineering 5*^{t}, daya pengadukan menggunakan dapat dihitung dengan persamaan berikut.

Dengan K_T = 0,87 (*Mc. Cabe & Smith - Unit Operations Of Chemical Engineering 5th, Page 254*)

$$P = \frac{K_T N^3 D_a^5 \rho}{g_c}$$

$$P = \frac{0{,}87 \times (1{,}9328 \text{ rps})^3 \times (1{,}1129 \text{ ft})^5 \times 64{,}9130 \text{ lb/ft}^3}{32{,}2 \text{ ft/s}^2}$$

P = 43,1436 ft.lbf/s

P = 0,0784 HP

h. Daya Motor

Efisiensi Motor = 80%

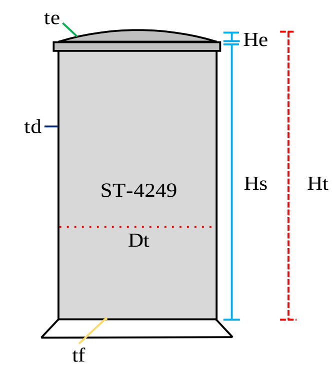
$$\text{Daya Motor} = \frac{0{,}0784 \text{ HP}}{80\%}$$

Daya Motor = 0,0980 HP

≈ 0,5 HP

26) *Storage Tank* Sabun Cair (ST-4249)

Fungsi	: Tempat menyimpan sabun cair
Tipe	: Silinder vertikal dengan alas datar dan tutup *elipsoidal*
Bahan konstruksi	: *Carbon steel 70 C-Si (SA-515 Grade 70)*
Jumlah	: 1 unit
Sifat bahan	: Tidak volatil, tidak korosif dan tidak higroskopis
Fasa	: Cair



Gambar LC-31. *Storage Tank* Sabun Cair

Data:

- Laju alir umpan : 2.525,2525 kg/jam : 5.567,1728 lb/jam
- Densitas campuran : 1.039,7732 kg/m^3 : 64,9130 lb/ft^3
- Tekanan : 1 atm
- Viskositas Campuran : 32,6 cP : 0,0022 lb/ft.s
- Lama Penyimpanan : 3 hari : 72 jam

1. Kapasitas Tangki

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

$$V_p = \frac{2.525,2525 \text{ kg/jam} \times 72 \text{ jam}}{1.039,7732 \text{ kg/m}^3}$$

$$V_p = 2,4287 \text{ m}^3$$

$$= 85,7671 \text{ ft}^3$$

$$= 148.208,3671 \text{ in}^3$$

$$= 641,5945 \text{ gal}$$

Dengan Mempertimbangkan faktor keamanan 10 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$$V_p = 0,9 V_t$$

$$V_t = \frac{V_p}{0,9}$$

$$V_t = \frac{2,4287\ m^3}{0,9}$$

$V_t = 2,6986\ m^3$

$= 95,2984\ ft^3$

$= 164.678,6756\ in^3$

$= 712,8946$ gal

2. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1,1775\ D_t^3$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0,1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + V_e$

$V_t = 1,1775\ D_t^3 + (0,1308\ D_t^3)$

$V_t = 1,3083\ D_t^3$

$$D_t^3 = \frac{V_t}{1,3083}$$

$$D_t^3 = \frac{2,6986\ m^3}{1,3083}$$

$$D_t = \sqrt[3]{\frac{2{,}6986\ m^3}{1{,}3083}}$$

D_t = 2,0627 m

= 4,1741 ft

= 50,1023 in

d. Tinggi Silinder

$H_s = 1{,}5\ D_t$

$H_s = 1{,}5 \times 2{,}0627$ m

H_s = 1,9089 m

= 6,2612 ft

= 75,1534 in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 2{,}0627$ m

H_e = 0,3182 m

= 1,0437 ft

= 12,5275 in

f. Tinggi Tangki

$H_t = H_s + H_e$

H_t = 1,9089 m + 0,3182 m

H_t = 2,2271 m

g. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s + (H_e))}{V_t}$$

$$H_c = \frac{2,4287\ m^3 \times (1,9089\ m + (0,3182\ m))}{2,6986\ m^3}$$

H_c = 2,0044 m

= 6,5744 ft

= 78,9132 in

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

P_c = 1.039,7732 kg/m^3 × 9,81 m/s^2 × 2,0044 m

P_c = 20.445,2310 kg.m/s^2

= 0,1983 atm

= 2,9142 psi

i. Tekanan Desain

$P_d = P_{op} + P_c$

P_d = 1 atm + 0,1983 atm

P_d = 1,1983 atm

= 17,6101 psi

P_d = 17,6101 psi

R = 25,0512 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{17,6101 \text{ psi} \times 25,0512 \text{ in}}{17500 \text{ psi} \times 0,85 - 0,6 \times 17,6101 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2297 in

= 0,0058 m

= 0,0190 ft

= 5,8344 mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0,2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{17,6101 \text{ psi} \times 50,1023 \text{ in}}{2 \times 17500 \text{ psi} \times 0,85 - 0,2 \times 17,6101 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2297 in

= 0,0058 m

= 0,0190 ft

= 5,8344 mm

l. Tebal Alas Tangki

$$t_f = D\sqrt{\frac{0{,}3\ P}{S}} + C$$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$$t_f = 50{,}1023\ in\sqrt{\frac{0{,}3 \times 17{,}6101\ psi}{17500\ psi}} + 0{,}02\ in/tahun \times 10\ tahun = 1{,}0705\ in$$

= 0,0272 m

= 0,0892 ft

= 27,1907 mm

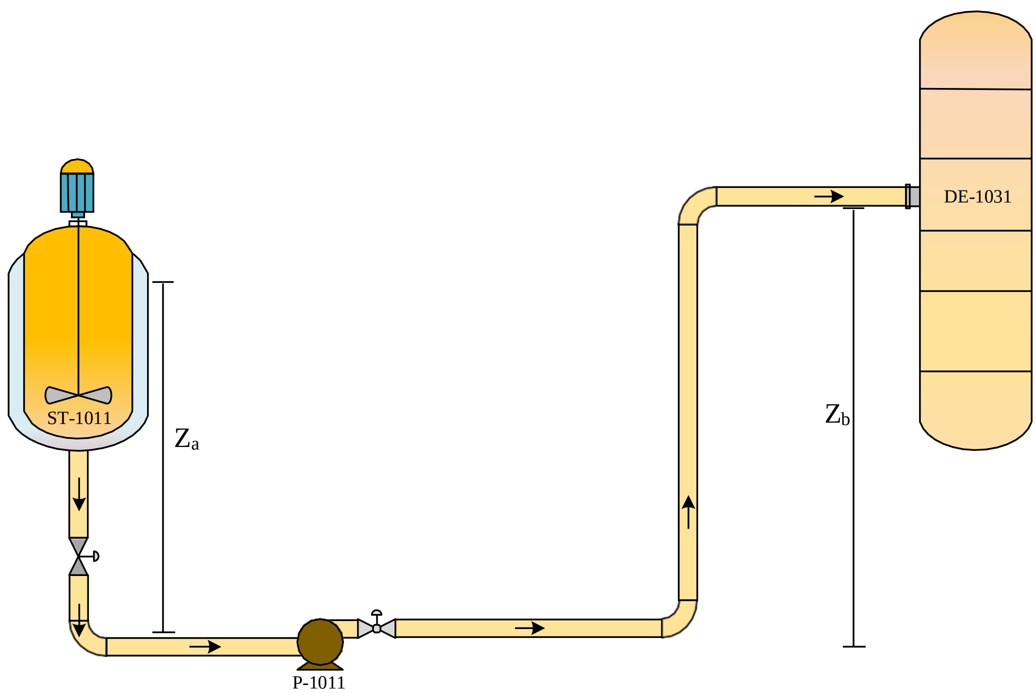
27) Pompa Alat Utama

Fungsi : Mengalirkan PFAD dari *storage tank* ke *deodorizer*

Tipe : *Centrifugal pump*

Bahan konstruksi : *Commercial steel pipe*

Jumlah : 1 unit



Gambar LC-32. Pompa P-1011

Data:

- Laju alir umpan : 1.341,5310 kg/jam : 0,8213 lb/s
- Densitas campuran : 879,8449 kg/m^3 : 54,9287 lb/ft^3
- Viskositas Campuran : 8,2309 cP : 19,9105 lb/ft.hr
- Tinggi pompa terhadap cairan masuk : 2 m : 6,5600 ft
- Tinggi pompa terhadap cairann keluar : 8 m : 26,2400 ft
- Panjang pipa hisap : 6 m : 19,68 ft
- Panjang pipa buang : 15 m : 49,2000 ft
- Faktor keamanan : 10%

1. Laju alir volumetrik

$$Q_p = \frac{m}{90\%}$$

$$Q_p = \frac{1.341,5310 \text{ kg/jam}}{90\%}$$

$$Q_p = 1.490,5900 \ \frac{kg}{jam} = 0.9126 \frac{lb}{s}$$

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

$$Q_v = \frac{1.490,5900 \text{ kg/jam}}{879,8449 \text{ kg/m}^3}$$

$$Q_v = 1,6942 \ \frac{m^3}{jam} = 0.0166 \frac{ft^3}{s} = 7,4591 \ \frac{gal}{min}$$

2. Diameter optimum

Asumsi aliran adalah turbulen

$D_{opt} = 3,9 \times Q_v^{0,45} \times \rho^{0,13}$ peter's pers 14.15

$$D_{opt} = 3,9 \times \left(0.0166 \frac{ft^3}{s}\right)^{0,45} \times \left(54,9287 \frac{lb}{ft^3}\right)^{0,13} = 1,0386 \text{ in} \approx 1 \text{ in}$$

Berdasarkan tabel 11 DQ Kern diperoleh pipa baja dengan ukuran sebagai berikut.

	Suction (a)			Discharge (b)		
IPS	**1 in Sch 80**					
	in	ft	m	in	ft	m
OD	1,3200	0,1100	0,0335	1,3200	0,1100	0,0335
ID	0,9570	0,0797	0,0243	0,9570	0,0797	0,0243
a"	0,7180	in^2	0,0050	ft^2		

3. Kecepatan aliran

$V_a = V_b$ karena ukuran pipa hisap dan pipa buang sama.

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

$$V = \frac{0.0166 \frac{ft^3}{s}}{0,0050\ ft^2} = 3,3322 \frac{ft}{s} = 11.995,9924 \frac{ft}{jam}$$

$$\frac{V^2}{2g_c} = \frac{3,3322 \frac{ft}{s}}{2 \times 32,17} = 0,1726 \frac{ft.\ lbf}{lb}$$

4. Bilangan *Reynold*

$$N_{Re} = \frac{\rho \times V \times ID}{\mu} \quad \text{Mc.cabe Pers 9.17}$$

$$N_{Re} = \frac{54,9287 \frac{lb}{ft^3} \times 11.995,9924 \frac{ft}{jam} \times 0,0797\ ft}{19,9105\ lb/ft.hr} = 2.638,2101\ \text{(Turbulen)}$$

5. Rugi gesek

a. Pipa hisap

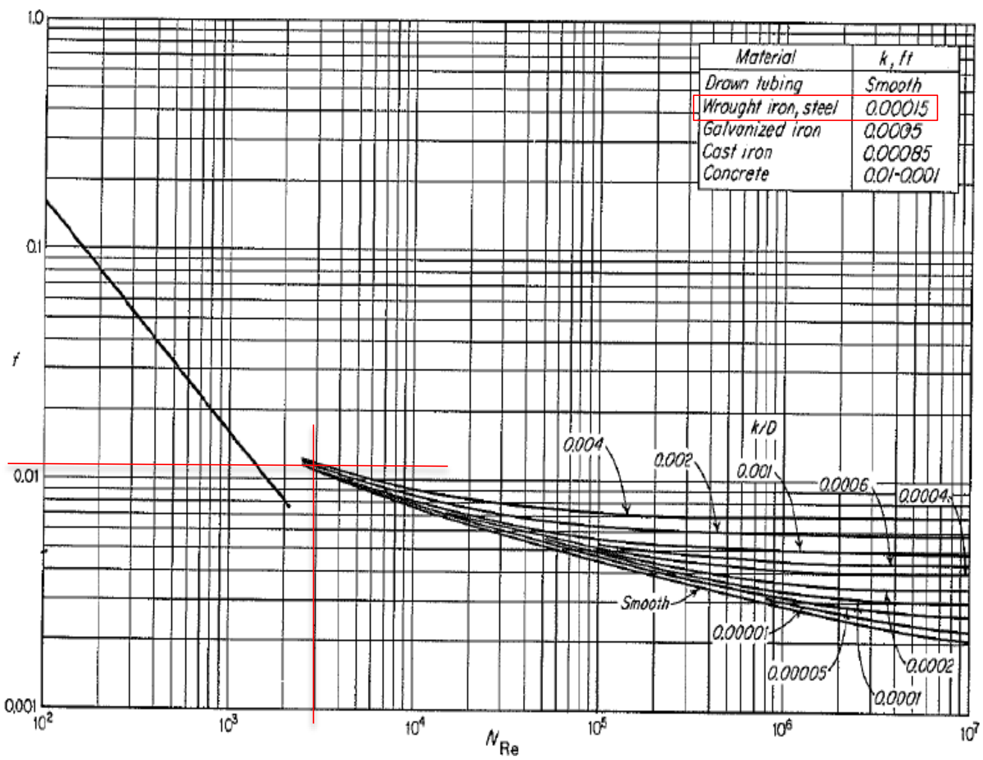
- Rugi gesek karena *skin*

$$h_{fsa} = f \frac{\Delta L V^2}{r_H 2g_c} \quad \text{Mc.cabe pers 5.56}$$

$$\text{Dengan } r_H = \frac{ID}{4} = \frac{0{,}0797 \text{ ft}}{4} = 0{,}0199 \text{ ft}$$

Material yang digunakan adalah *wroght iron, steel* dengan nilai k = 0,00015 ft.

$$\frac{k}{ID} = \frac{0{,}00015 \text{ ft}}{0{,}0797 \text{ ft}} = 0{,}00188$$



Dari gambar diatas diperoleh nilai f = 0,02

$$h_{fsa} = 0{,}02 \frac{19{,}68 \text{ ft} \times 0{,}1726 \ \frac{\text{ft. lbf}}{\text{lb}}}{0{,}0199 \text{ ft}} = 3{,}4084 \ \frac{\text{ft. lbf}}{\text{lb}}$$

- Rugi gesek karena *fitting*

Fitting yang digunakan adalah 1 buah elbow 90^o dengan nilai k_f = 0,9 dan 1 buah *gate valve* dengan nilai k_f = 0,2.

$h_{ffa} = k_f \frac{V^2}{2g_c}$ Mc.cabe pers 5.67

$h_{ffa} = (1 \times 0{,}9) + (1 \times 0{,}2) \times 0{,}1726 \ \frac{ft.\ lbf}{lb} = 0{,}1898 \ \frac{ft.\ lbf}{lb}$

- Rugi gesek karena kontraksi (dari tangki ke pipa)

  $h_{fc} = k_c \frac{V^2}{2g_c}$ Mc.cabe pers 5.65

  Dengan $k_c = 0{,}4 \times (1 - \frac{s_b}{s_a})$

  Dikarenakan $S_a >>> S_b$ sehingga nilai dari $\frac{S_b}{S_a} = 0$ maka nilai $k_c = 0{,}4$

  $h_{fc} = 0{,}4 \times 0{,}1726 \ \frac{ft.\ lbf}{lb} = 0{,}0690 \ \frac{ft.\ lbf}{lb}$

  Rugi gesek *suction* = 3,6672 ft.lbf/lb

b. Pipa buang

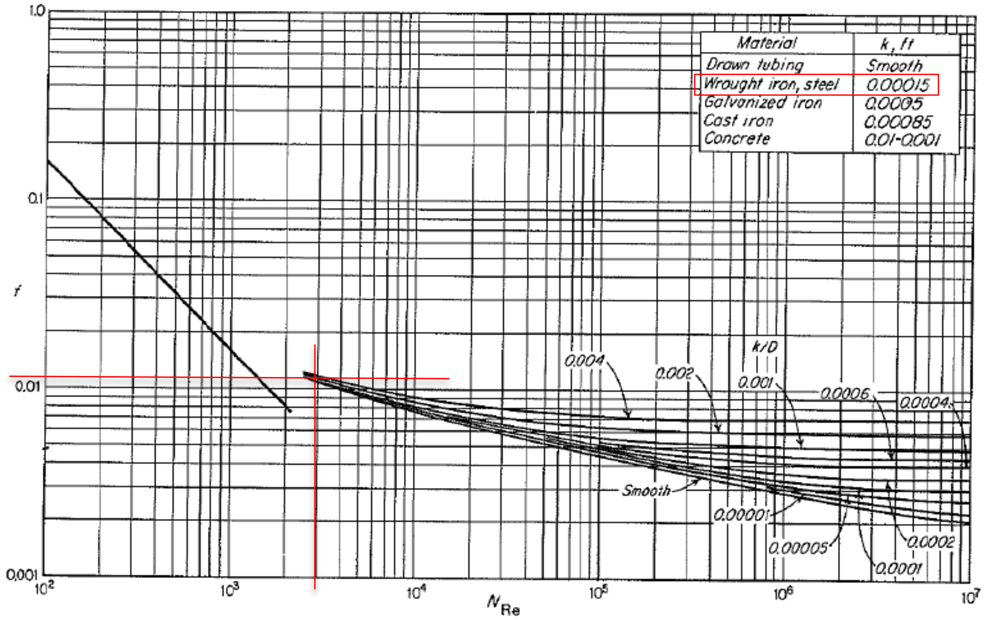
- Rugi gesek karena *skin*

  $h_{fsa} = f \frac{\Delta L V^2}{r_H 2g_c}$ Mc.cabe pers 5.56

  Dengan $r_H = \frac{ID}{4} = \frac{0{,}0797\ ft}{4} = 0{,}0199\ ft$

  Material yang digunakan adalah *wroght iron, steel* dengan nilai k = 0,00015 ft.

  $\frac{k}{ID} = \frac{0{,}00015\ ft}{0{,}0797\ ft} = 0{,}00188$



Dari gambar diatas diperoleh nilai f = 0,02

$$h_{fsa} = 0{,}02 \frac{72{,}16 \text{ ft} \times 0{,}1726 \ \frac{\text{ft. lbf}}{\text{lb}}}{0{,}0199 \text{ ft}} = 12{,}4973 \ \frac{\text{ft. lbf}}{\text{lb}}$$

- Rugi gesek karena *fitting*

Fitting yang digunakan adalah 2 buah elbow 90^o dengan nilai k_f = 0,9 dan 1 buah *globe valve* dengan nilai k_f = 10.

$$h_{ffa} = k_f \frac{V^2}{2g_c} \quad \text{Mc.cabe pers 5.67}$$

$$h_{ffa} = (2 \times 0{,}9) + (1 \times 10) \times 0{,}1726 \ \frac{\text{ft. lbf}}{\text{lb}} = 2{,}0364 \ \frac{\text{ft. lbf}}{\text{lb}}$$

- Rugi gesek karena ekspansi (dari pipa ke tangki)

$$h_{fe} = k_e \frac{V^2}{2g_c} \quad \text{Mc.cabe pers 5.69}$$

Dengan $k_e = 1 \times (1 - \frac{s_a}{s_b})^2$

Dikarenakan $S_b >>> S_a$ sehingga nilai dari $\frac{S_a}{S_b} = 0$ maka nilai $k_e = 1$

$h_{fe} = 1 \times 0{,}1726 \ \frac{ft.\ lbf}{lb} = 0{,}1726 \ \frac{ft.\ lbf}{lb}$

Rugi gesek *discharge* = 14,7063 ft.lbf/lb

Rugi gesek total = 18,3735 ft.lbf/lb

6. Daya pompa

$$\frac{P_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a V_a^2}{2g_c} + \eta W_p = \frac{P_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b V_b^2}{2g_c} + h_f$$ pers bernoulli Mc.cabe pers 4.32

Dengan,

$P_a = P_b$

$V_a = V_b$

$\rho_a = \rho_b$

$\alpha_a = \alpha_b$

$\frac{g}{g_c} = \frac{g}{g_c}$

Kemudian efisiensi dari pompa dapat dicari dengan menggunakan gambar 14.37 peter's.

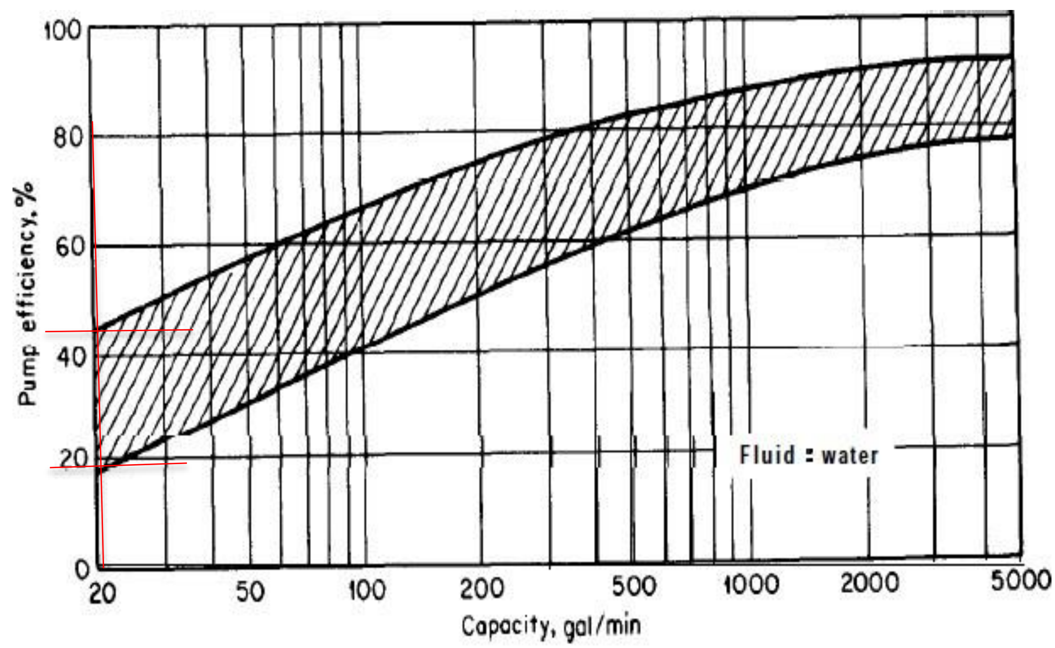


FIGURE 1437
Efficiencies of centrifugal pumps.

Dari gambar 14.37 diperoleh efisiensi pompa sebesar 45%

$$W_p = \frac{(Z_b - Z_a) + h_f}{\eta}$$

$$W_p = \frac{(32{,}8\ \text{ft} - 26{,}24\ \text{ft}) + 18{,}3735\ \frac{\text{ft.lbf}}{\text{lb}}}{45\%} = 55{,}4078\ \frac{\text{ft.lbf}}{\text{lb}}$$

7. *Broke horse power* (BHP)

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

$$BHP = \frac{55{,}4078\ \frac{\text{ft.lbf}}{\text{lb}} \times 0{,}8213\ \frac{\text{lb}}{\text{s}}}{550} = 0{,}0827\ \text{HP}$$

8. *Motor horse power* (MHP)

Efisiensi motor = 80% (gambar 14.38 peter's)

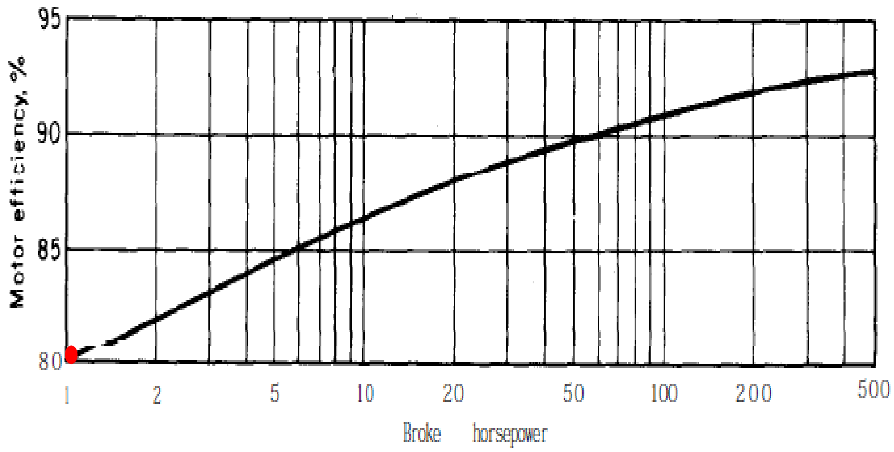


FIGURE 1438
Efficiencies of three-phase motors.

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

$$MHP = \frac{0,0827\ HP}{80\%} = 0,1034\ HP \approx 0,5\ HP$$

Dengan cara yang sama maka diperoleh daya pompa untuk alat proses sebagai berikut.

Tabel LC.1 Daya Pompa Pada Peralatan Proses

Kode alat	Z_a (ft)	Z_b (ft)	h_f (ft.lbf/lb)	Efisiensi Pompa (%)	W_p (ft.lbf/lb)	BHP (HP)	Efisiensi Motor (%)	MHP (HP)
P-1031	6,56	13,12	1,4664	45	17,8365	0,0254	80	0,5
P-1071	0	9,84	1,3378	45	24,8396	0,0017	80	0,5
P-1122	6,56	13,12	2,1477	45	19,3504	0,0223	80	0,5

P-2122	6,56	13,12	2,0263	45	19,0807	0,0491	80	0,5
P-3141	6,56	16,4	1,5607	45	25,3349	0,0620	80	0,5
P-4207	0	16,4	2,5897	45	42,1994	0,0129	80	0,5
P-4208	0	13,12	0,0897	45	29,3549	0,0002	80	0,5
P-4212	8,2	13,12	2,3227	45	16,0948	0,0452	80	0,5
P-4223	6,56	13,12	2,5724	45	20,2941	0,0570	80	0,5

B. Spesifikasi Peralatan Utilitas

1) Pompa Alat Pengolahan Air

Dengan cara yang sama maka diperoleh daya pompa untuk alat proses sebagai berikut.

Tabel LC.2 Daya Pompa Pada Peralatan Utilitas

Kode alat	Z_a (ft)	Z_b (ft)	h_f (ft.lbf/lb)	Efisiensi Pompa (%)	W_p (ft.lbf/lb)	BHP (HP)	Efisiensi Motor (%)	MHP (HP)
P-1011	22,96	15,41	2,7881	75	54,8854	2,8085	83	4
P-1021	4,92	6,13	2,1771	75	4,5210	0,2892	80	0,5
P-2032	0	5,91	0,0391	75	13,2069	0,0001	80	0,5
P-2043	0	5,91	534,25	45	1200,35	0,0012	80	0,5
P-2054	0	5,91	288,25	45	653,66	0,0007	80	0,5
P-2071	0	8,53	1,9929	75	14,0279	0,7178	80	1
P-2081	8,53	16,4	2,2066	75	13,4381	0,6876	80	1
P-3091	0	16,4	3,3483	75	27,2057	1,3921	80	2
P-3101	3,28	13,12	1,9020	75	15,6561	0,8011	80	1
P-3115	0	6,56	3,4392	75	13,3322	0,6872	80	1
P-3121	3,28	13,12	2,9579	75	17,0639	0,8425	80	1
P-3141	3,28	13,12	4,2381	45	31,2847	0,1055	80	0,5
P-3136	3,28	13,12	3,8296	45	30,3769	0,1025	80	0,5

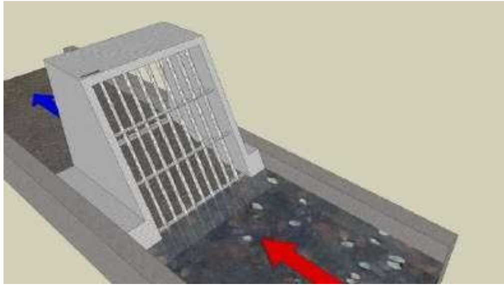
2) *Screening* (BS-1011)

Fungsi : Menyaring partikel-partikel padat yang berukuran besar dari air sungai

Tipe : *Bar screen*

Bahan konstruksi : *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*

Jumlah : 1 unit



Gambar LC-33. *Screening*

Data:

- Laju alir umpan : 45.968,95 kg/jam
- Laju alir volumetrik : 45,96985 m^3/jam : 0,0128 m^3/s
- Densitas campuran : 1.000 kg/m^3
- Tekanan : 1 atm
- Temperatur : 30 ^oC

Digunakan ukuran *bar* standar dengan dimensi sebagai berikut.

Lebar *bar* = 5 mm

Tebal *bar* = 20 mm

Bar clear spacing = 20 mm

Slope = 28^o

Direncanakan ukuran *screening* dengan dimensi sebagai berikut.

Panjang *screen* = 2 m

Lebar *screen* = 2 m

Misalkan jumlah bar = x , maka

5x + 2(x + 1) = 2000

25x = 1980

x = 79 buah bar

Luas bukaan

A = 20x (x + 1) × 2000

A = 20 × 79(79 + 1) × 2000 = 3.208.000 mm^2 = 3,208 m^2

Asumsi C_d=0,6 dan 30% screen tersumbat, maka

$$\text{Head loss } (\Delta H) = \frac{Q^2}{2gC_d^{\,2}A^2}$$

$$\text{Head loss } (\Delta H) = \frac{(0{,}0128\ m^3/s)^2}{2 \times 9{,}81 \frac{m}{s^2} \times 0{,}6^2 \times (3{,}208\ m^2)^2} = 0{,}00036$$

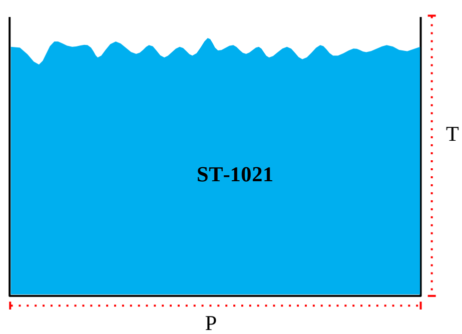
3) Bak Pengendapan Awal (ST-1021)

Fungsi : Menampung air sungai dan diendapkan sebelum diolah ke proses selanjutnya

Tipe : Persegi panjang

Bahan konstruksi : Beton bertulang

Jumlah : 2 unit



Gambar LC-34. Bak Pengendapan Awal

Data:

- Laju alir umpan : 45968,9530 kg/jam
- Laju alir volumetrik : 45,9690 m^3/jam : 0,0128 m^3/s
- Densitas campuran : 1.000 kg/m^3
- Lama penyimpanan : 24 jam
- Tekanan : 1 atm
- Temperatur : 30 ^oC

$$V = Q \times t$$

$$V = 45{,}9690 \frac{m^3}{jam} \times 24 \text{ jam} = 1.103{,}2549 \text{ m}^3$$

Direncanakan akan digunakan 2 unit bak, sehingga kapasitas asing-masing adalah

$$V = 1.103{,}2549 \text{ m}^3 / 2 = 551{,}6274 \text{ m}^3$$

Faktor keamanan = 20%

$$V_p = \frac{V}{0{,}8}$$

$$V_p = \frac{551{,}6274 \text{ m}^3}{0{,}8} = 689{,}5343 \text{ m}^3$$

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

$$V = P \times L \times T$$

$$689{,}5343 \text{ m} = 3T \times 2T \times T$$

$$6T^3 = 689{,}5343 \text{ m}$$

$$T = \sqrt[3]{\frac{689{,}5343 \text{ m}}{6}} = 4{,}8542 \text{ m}$$

$$P = 3T$$

$$P = 3 \times 4{,}8542 \text{ m} = 14{,}5625 \text{ m}$$

L = 2T

L = 2 × 4,8542 m = 9,7083 m

4) Tangki Pelarutan PAC (ST-2032)

Fungsi : Tempat melarutkan PAC

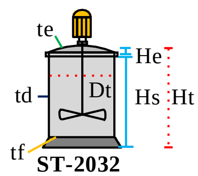
Tipe : Silinder vertikal dengan alas datar dan tutup *elipsoidal*

Bahan konstruksi : *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*

Jumlah : 1 unit

Sifat bahan : Tidak volatil, korosif dan tidak higroskopis

Fasa : Cair



Gambar LC-35. Tangki Pelarutan PAC

Data:

- Laju alir umpan : 45.968,9530 kg/jam : 101.343,1538 lb/jam
- Densitas campuran : 1.172,5 kg/m^3 : 73,1992 lb/ft^3
- Tekanan : 1 atm
- Viskositas campuran : 1 cP : 0,0007 lb/ft.s
- Lama penyimpanan : 5 hari : 120 jam

1. Kebutuhan PAC

Kekeruhan air sungai dumai diperkirakan sebesar 113,67 NTU

Penggunaan PAC :150,0000 mg/liter : 0,1500 kg/m^3

: 6,8953 kg/jam : 165,4882 kg/hari

PAC yang digunakan berupa larutan dengan konsentrasi 25%, sehingga :

m PAC = 25% × 165,4882 kg/hari = 41,3721 kg/hari = 1,7238 kg/jam

V PAC = 6,8953 kg/jam × 1.172,5 kg/m^3 = 0,0059 m^3 /jam = 0,1411 m^3/hari

2. Kapasitas Tangki

$V_p = V \times t$

V_p = 0,0059 m^3 /jam×120 jam

V_p = 0,7057 m^3

Dengan Mempertimbangkan faktor keamanan 20 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$V_p = 0{,}8\ V_t$

$$V_t = \frac{V_p}{0{,}8}$$

$$V_t = \frac{0{,}7057\ m^3}{0{,}8}$$

V_t = 0,8821 m^3

3. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1{,}1775\ D_t^3$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^{\,2} \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0{,}1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + V_e$

$V_t = 1{,}1775\ D_t^3 + (0{,}1308\ D_t^3)$

$V_t = 1{,}3083\ D_t^3$

$$D_t^3 = \frac{V_t}{1{,}3083}$$

$$D_t^3 = \frac{0{,}8821\ m^3}{1{,}3083}$$

$$D_t = \sqrt[3]{\frac{0{,}8821\ m^3}{1{,}3083}}$$

$D_t = 0{,}8770$ m

= 2,8766 ft

= 34,5275 in

d. Tinggi Silinder

$H_s = 1{,}5\ D_t$

$H_s = 1{,}5 \times 0{,}8770$ m

$H_s = 1{,}3155$ m

= 4,3148 ft

= 51,7912 in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 0{,}8770$ m

$H_e = 0{,}2192$ m

= 0,7191 ft

= 8,6319 in

f. Tinggi Tangki

$H_t = H_s + H_e$

$H_t = 1{,}3155 \text{ m} + 0{,}2192 \text{ m}$

$H_t = 1{,}5347 \text{ m}$

g. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s + (H_e))}{V_t}$$

$$H_c = \frac{0{,}7057 \text{ m}^3 \times (1{,}3155 \text{ m} + (0{,}2192 \text{ m}))}{0{,}8821 \text{ m}^3}$$

$H_c = 1{,}2278 \text{ m}$

$= 4{,}0272 \text{ ft}$

$= 48{,}3385 \text{ in}$

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

$P_c = 1.172{,}5000 \text{ kg/m}^3 \times 9{,}81 \text{ m/s}^2 \times 1{,}2278 \text{ m}$

$P_c = 14.122{,}4246 \text{ kg.m/s}^2$

$= 0{,}1370 \text{ atm}$

$= 2{,}0132 \text{ psi}$

i. Tekanan Desain

$P_d = P_{op} + P_c$

$P_d = 1 \text{ atm} + 0{,}1370 \text{ atm}$

$P_d = 1{,}1370 \text{ atm}$

$= 16{,}7137 \text{ psi}$

$P_d = 16{,}7137 \text{ psi}$

R = 17,2637 in

S = 18700 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{16,7137 \text{ psi} \times 17,2637 \text{ in}}{18700 \text{ psi} \times 0,85 - 0,6 \times 16,7137 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2182 in

= 0,0055 m

= 0,0182 ft

= 5,414 mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0,2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{16{,}7137 \text{ psi} \times 34{,}5275 \text{ in}}{2 \times 18700 \text{ psi} \times 0{,}85 - 0{,}2 \times 16{,}7137 \text{ psi}} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2182 in

= 0,0055 m

= 0,0182 ft

= 5,5411 mm

l. Tebal Alas Tangki

$$t_f = D\sqrt{\frac{0{,}3\ P}{S}} + C$$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$$t_f = 34{,}5275 \text{ in}\sqrt{\frac{0{,}3 \times 16{,}7137 \text{ psi}}{18700 \text{ psi}}} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun} = 0{,}76554 \text{ in}$$

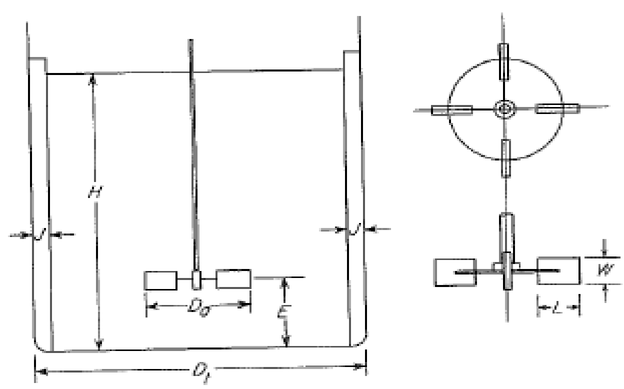
= 0,0194 m

= 0,0638 ft

= 19,4407 mm

4. Desain Pengaduk

Viskositas umpan < 4000 cP, maka dipilih *propeller* berdaun tiga (Kecepatan 1800 rpm) (*Walas - Selection Design & Chemical Process Equipment ed 1st, Page 288*).



Gambar LC-36. Desain Pengaduk Tangki Pelarutan PAC

a. Diameter Pengaduk

$$d = \frac{D_t}{3}$$

$$d = \frac{0{,}8770 \text{ m}}{3}$$

d = 0,2923 m

= 0,9589 ft

b. Panjang Daun Pengaduk

$$L = \frac{d}{4}$$

$$L = \frac{0{,}2923 \text{ m}}{4}$$

L = 0,0731 m

= 0,2397 ft

c. Lebar Daun Pengaduk

$$W = \frac{d}{5}$$

$$W = \frac{0{,}2923 \text{ m}}{5}$$

W = 0,0585 m

= 0,1918 ft

d. Tinggi Pengaduk Dari Dasar Tangki

$$E = \frac{D_t}{3}$$

$$E = \frac{0{,}8770 \text{ m}}{3}$$

E = 0,2923 m

= 0,9589 ft

e. Lebar *Baffle*

$$J = \frac{D_t}{12}$$

$$J = \frac{0{,}8770\ m}{12}$$

$J =$ 0,0731 m

= 0,2397 ft

f. Kecepatan Putar Pengaduk

Berdasarkan persamaan 6-18 *Robert Treyball-Mass Transfer Operation,* kecepatan putar pengaduk dapat dihitung dengan persamaan berikut.

Dengan $g_c = 32{,}2\ ft/s^2$

σ = 72,75 dyn/cm (*Mc.cabe – Unit Operation Of Chemical Engineering 5th Page 274*).

= 0,0537 lb/ft

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

$$\frac{N_d}{\left(\frac{0{,}0537\ lb/ft \times 32{,}2\ ft/s^2}{73{,}1992\ lb/ft^3}\right)^{0,25}} = 1{,}22 + 1{,}25\ \left(\frac{2{,}8766\ ft}{0{,}9589\ ft}\right)$$

$N_d = 2{,}7785$ rps

g. Daya Pengadukan

Berdasarkan persamaan 9-17 *Mc.cabe – Unit Operation Of Chemical Engineering 5^{t},* bilangan *reynold* dapat dihitung dengan persamaan berikut.

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

$$N_{Re} = \frac{73{,}1992\ lb/ft^3 \times 2{,}7785\ rps \times (0{,}9589\ ft)^2}{0{,}0007\ lb/ft.s}$$

N_{Re} = 278.257,5403

Karena Nre > 10.000, maka berdasarkan persamaan 9.24 *Mc.cabe – Unit Operation Of Chemical Engineering 5^t^*, daya pengadukan menggunakan dapat dihitung dengan persamaan berikut.

Dengan K_T = 0,87 (*Mc. Cabe & Smith - Unit Operations Of Chemical Engineering 5th, Page 254*)

$$P = \frac{K_T N^3 D_a^5 \rho}{g_c}$$

$$P = \frac{0,87 \times (2,7785\ rps)^3 \times (0,9589\ ft)^5 \times 73,1992\ lb/ft^3}{32,2\ ft/s^2}$$

P = 34,3833 ft.lbf/s

P = 0,0625 HP

h. Daya Motor

Efisiensi Motor = 80%

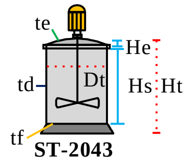
$$\text{Daya Motor} = \frac{0,0625\ HP}{80\%}$$

Daya Motor = 0,0781 HP

≈ 0,5 HP

5) Tangki Pelarutan Kapur Tohor (ST-2043)

Fungsi	: Tempat melarutkan kapur tohor
Tipe	: Silinder vertikal dengan alas datar dan tutup *elipsoidal*
Bahan konstruksi	: *Carbon steel 70 C-Si (SA-515 Grade 70)*
Jumlah	: 1 unit
Sifat bahan	: Tidak volatil, tidak korosif dan tidak higroskopis
Fasa	: Cair



Gambar LC-37. Tangki Pelarutan Kapur Tohor

Data:

- Laju alir umpan : 45.968,9530 kg/jam : 101.343,1538 lb/jam
- Densitas campuran : 1.485,1370 kg/m^3 : 92,7171 lb/ft^3
- Tekanan : 1 atm
- Viskositas campuran : 0,4628 cP : 0,0003 lb/ft.s
- Lama penyimpanan : 5 hari : 120 jam

1. Kebutuhan Kapur Tohor

   Kekeruhan air sungai dumai diperkirakan sebesar 113,67 NTU

   Penggunaan kapur tohor :15,0000 mg/liter : 0,0150 kg/m^3

   : 0,6895 kg/jam : 16,5488 kg/hari

Kapur tohor yang digunakan berupa larutan dengan konsentrasi 40%, sehingga :

m kapur tohor = 40% × 16,5488 kg/hari = 4,1372 kg/hari = 0,1724 kg/jam

V kapur tohor = 0,6895 kg/jam×1.485,1370 kg/m^3 = 0,0005 m^3 /jam = 0,0111 m^3/hari

2. Kapasitas Tangki

   $V_p = V \times t$

   $V_p = 0{,}0005\ m^3/\text{jam} \times 120\ \text{jam}$

   $V_p = 0{,}0557\ m^3$

Dengan Mempertimbangkan faktor keamanan 20 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$V_p = 0{,}8\ V_t$

$$V_t = \frac{V_p}{0,8}$$

$$V_t = \frac{0,0557\ m^3}{0,8}$$

$$V_t = 0,0696\ m^3$$

3. Dimensi Tangki

a. Volume Silinder

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

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

$$V_s = 1,1775\ D_t^3$$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

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

c. Diameter Tangki

$$V_t = V_s + V_e$$

$$V_t = 1,1775\ D_t^3 + (0,1308\ D_t^3)$$

$$V_t = 1,3083\ D_t^3$$

$$D_t^3 = \frac{V_t}{1,3083}$$

$$D_t^3 = \frac{0,0696\ m^3}{1,3083}$$

$$D_t = \sqrt[3]{\frac{0,0696\ m^3}{1,3083}}$$

D_t = 0,3698 m

= 1,2131 ft

= 14,5607 in

d. Tinggi Silinder

$H_s = 1,5\ D_t$

$H_s = 1,5 \times 0,3698$ m

H_s = 0,5548 m

= 1,8196 ft

= 21,8410 in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 0,3698$ m

H_e = 0,0925 m

= 0,3033 ft

= 3,6402 in

f. Tinggi Tangki

$H_t = H_s + H_e$

H_t = 0,5548 m + 0,0925 m

H_t = 0,6472 m

g. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s + (H_e))}{V_t}$$

$$H_c = \frac{0,0557\ m^3 \times (0,5548\ m + (0,0925\ m))}{0,0696\ m^3}$$

H_c = 0,5178 m

= 1,6983 ft

= 20,3849 in

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

P_c = 1.485,1370 kg/m^3× 9,81 m/s^2 × 0,5178 m

P_c = 7.543,6103 kg.m/s^2

= 0,0732 atm

= 1,0753 psi

i. Tekanan Desain

$P_d = P_{op} + P_c$

P_d = 1 atm + 0,0732 atm

P_d = 1,0732 atm

= 15,7756 psi

P_d = 15,7756 psi

R = 7,2803 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{15,7756 \text{ psi} \times 7,2803 \text{ in}}{17500 \text{ psi} \times 0,85 - 0,6 \times 15,7756 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2077 in

= 0,0053 m

= 0,0173 ft

= 5,2762 mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0,2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{15,7756 \text{ psi} \times 14,5607 \text{ in}}{2 \times 17500 \text{ psi} \times 0,85 - 0,2 \times 15,7756 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2077 in

= 0,0053 m

= 0,0173 ft

= 5,2761 mm

l. Tebal Alas Tangki

$t_f = D\sqrt{\frac{0,3\ P}{S}} + C$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$$t_f = 14,5607 \text{ in}\sqrt{\frac{0,3 \times 15,7756 \text{psi}}{17500 \text{ psi}}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun} = 0,4395 \text{ in}$$

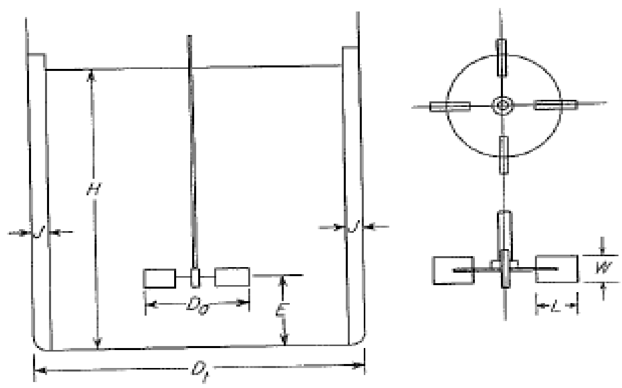
$= 0,0112$ m

$= 0,0366$ ft

$= 11,1620$ mm

4. Desain Pengaduk

Viskositas umpan < 4000 cP, maka dipilih *propeller* berdaun tiga (Kecepatan 1800 rpm) (*Walas - Selection Design & Chemical Process Equipment ed 1st, Page 288*).



Gambar LC-38. Desain Pengaduk Tangki Pelarutan Kapur Tohor

a. Diameter Pengaduk

$$d = \frac{D_t}{3}$$

$$d = \frac{0,3698 \text{ m}}{3}$$

$d = 0,1233$ m

$= 0,4044$ ft

b. Panjang Daun Pengaduk

$$L = \frac{d}{4}$$

$$L = \frac{0,1233 \text{ m}}{4}$$

L = 0,0308 m

= 0,1011 ft

c. Lebar Daun Pengaduk

$$W = \frac{d}{5}$$

$$W = \frac{0,1233 \text{ m}}{5}$$

W = 0,0247 m

= 0,0809 ft

d. Tinggi Pengaduk Dari Dasar Tangki

$$E = \frac{D_t}{3}$$

$$E = \frac{0,3698 \text{ m}}{3}$$

E = 0,1233 m

= 0,4044 ft

e. Lebar *Baffle*

$$J = \frac{D_t}{12}$$

$$J = \frac{0,3698 \text{ m}}{12}$$

J = 0,0308 m

= 0,1011 ft

f. Kecepatan Putar Pengaduk

Berdasarkan persamaan 6-18 *Robert Treyball-Mass Transfer Operation,* kecepatan putar pengaduk dapat dihitung dengan persamaan berikut.

Dengan g_c = 32,2 ft/s^2

σ = 72,75 dyn/cm (*Mc.cabe – Unit Operation Of Chemical Engineering 5th Page 274*).

= 0,0537 lb/ft

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

$$\frac{N_d}{\left(\frac{0,0537\ lb/ft \times 32,2\ ft/s^2}{92,7171\ lb/ft^3}\right)^{0,25}} = 1,22 + 1,25\ \left(\frac{1,2131\ ft}{0,4044\ ft}\right)$$

N_d = 6,3836 rps

g. Daya Pengadukan

Berdasarkan persamaan 9-17 *Mc.cabe – Unit Operation Of Chemical Engineering 5^{t},* bilangan *reynold* dapat dihitung dengan persamaan berikut.

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

$$N_{Re} = \frac{92,7171\ lb/ft^3 \times 6,3836\ rps \times (0,4044\ ft)^2}{0,0003\ lb/ft.s}$$

N_{Re} = 311.173,7976

Karena Nre > 10.000, maka berdasarkan persamaan 9.24 *Mc.cabe – Unit Operation Of Chemical Engineering 5^{t},* daya pengadukan menggunakan dapat dihitung dengan persamaan berikut.

Dengan K_T = 0,87 (*Mc. Cabe & Smith - Unit Operations Of Chemical Engineering 5th, Page 254*)

$$P = \frac{K_T N^3 D_a^5 \rho}{g_c}$$

$$P = \frac{0{,}87 \times (6{,}3836\ rps)^3 \times (0{,}4044\ ft)^5 \times 92{,}7171\ lb/ft^3}{32{,}2\ ft/s^2}$$

P = 7,0448 ft.lbf/s

P = 0,0128 HP

h. Daya Motor

Efisiensi Motor = 80%

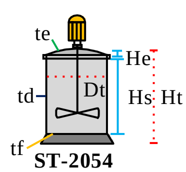
$$\text{Daya Motor} = \frac{0{,}0128\ HP}{80\%}$$

Daya Motor = 0,0160 HP

≈ 0,5 HP

6) Tangki Pelarutan Kaporit (ST-2054)

Fungsi	: Tempat melarutkan kaporit
Tipe	: Silinder vertikal dengan alas datar dan tutup *elipsoidal*
Bahan konstruksi	: *Stainless steel 18 Cr-8 Ni (SA-240 Grade 304)*
Jumlah	: 1 unit
Sifat bahan	: Tidak volatil, korosif dan tidak higroskopis
Fasa	: Cair



Gambar LC-39. Tangki Pelarutan Kaporit

Data:

- Laju alir umpan : 45.968,9530 kg/jam : 101.343,1538 lb/jam

- Densitas campuran : 1.180,0000 kg/m^3 : 73,6674 lb/ft^3
- Tekanan : 1 atm
- Viskositas campuran : 0,7600 cP : 0,0005 lb/ft.s
- Lama penyimpanan : 5 hari : 120 jam

1. Kebutuhan Kaporit

   Kekeruhan air sungai dumai diperkirakan sebesar 113,67 NTU

   Penggunaan kapur tohor :20,0000 mg/liter : 0,0200 kg/m^3

   : 0,9194 kg/jam : 22,0651 kg/hari

Kapur tohor yang digunakan berupa larutan dengan konsentrasi 40%, sehingga :

m kapur tohor = 40% × 22,0651 kg/hari = 5,5163 kg/hari = 0,2298 kg/jam

V kapur tohor = 0,9194 kg/jam×1.180,0000 kg/m^3 = 0,0008 m^3 /jam = 0,0187 m^3/hari

2. Kapasitas Tangki

$V_p = V \times t$

$V_p = 0{,}0008\ m^3/jam \times 120\ jam$

$V_p = 0{,}0935\ m^3$

Dengan Mempertimbangkan faktor keamanan 20 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$V_p = 0{,}8\ V_t$

$$V_t = \frac{V_p}{0{,}8}$$

$$V_t = \frac{0{,}0935\ m^3}{0{,}8}$$

$V_t = 0{,}1169\ m^3$

3. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1,1775\ D_t^3$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4, Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0,1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + V_e$

$V_t = 1,1775\ D_t^3 + (0,1308\ D_t^3)$

$V_t = 1,3083\ D_t^3$

$$D_t^3 = \frac{V_t}{1,3083}$$

$$D_t^3 = \frac{0,1169\ m^3}{1,3083}$$

$$D_t = \sqrt[3]{\frac{0,1169\ m^3}{1,3083}}$$

$D_t = 0,4474$ m

= 1,4674 ft

= 17,6136 in

d. Tinggi Silinder

$H_s = 1,5\ D_t$

$H_s = 1,5 \times 0,4474$ m

$H_s = 0,6711$ m

= 2,2011 ft

$= 26{,}4203$ in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 0{,}4474$ m

$H_e = 0{,}1118$ m

$= 0{,}3669$ ft

$= 4{,}4034$ in

f. Tinggi Tangki

$H_t = H_s + H_e$

$H_t = 0{,}6711\ \text{m} + 0{,}1118\ \text{m}$

$H_t = 0{,}7829$ m

g. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s + (H_e))}{V_t}$$

$$H_c = \frac{0{,}0935\ \text{m}^3 \times (0{,}6711\ \text{m} + (0{,}1118\ \text{m}))}{0{,}1169\ \text{m}^3}$$

$H_c = 0{,}6263$ m

$= 2{,}0544$ ft

$= 24{,}6590$ in

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

$P_c = 1.180{,}0000\ \text{kg/m}^3 \times 9{,}81\ \text{m/s}^2 \times 0{,}6263\ \text{m}$

$P_c = 7.250{,}3820\ \text{kg.m/s}^2$

$= 0{,}0703$ atm

$= 1{,}0335$ psi

i. Tekanan Desain

$P_d = P_{op} + P_c$

P_d = 1 atm + 0,0703 atm

P_d = 1,0703 atm

= 15,7338 psi

P_d = 15,7338 psi

R = 8,8068 in

S = 18700 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0{,}6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{15{,}7338 \text{ psi} \times 8{,}8068 \text{ in}}{18700 \text{ psi} \times 0{,}85 - 0{,}6 \times 15{,}7338 \text{ psi}} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2087 in

= 0,0053 m

= 0,0174 ft

= 5,3016 mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0,2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{15,7338 \text{ psi} \times 17,6136 \text{ in}}{2 \times 18700 \text{ psi} \times 0,85 - 0,2 \times 15,7338 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2087 in

= 0,0053 m

= 0,0174 ft

= 5,3014 mm

l. Tebal Alas Tangki

$t_f = D\sqrt{\frac{0,3\ P}{S}} + C$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$$t_f = 17,6136 \text{ in}\sqrt{\frac{0,3 \times 17,6136 \text{ psi}}{18700 \text{ psi}}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun} = 0,4798 \text{ in}$$

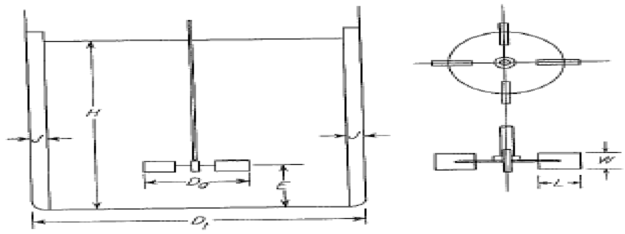
= 0,0122 m

= 0,0400 ft

= 12,1878 mm

4. Desain Pengaduk

Viskositas umpan < 4000 cP, maka dipilih *propeller* berdaun tiga (Kecepatan 1800 rpm) (*Walas - Selection Design & Chemical Process Equipment ed 1st, Page 288*).



Gambar LC-40. Desain Pengaduk Tangki Pelarutan Kaporit

a. Diameter Pengaduk

$$d = \frac{D_t}{3}$$

$$d = \frac{0,4474 \text{ m}}{3}$$

$$d = 0,1491 \text{ m}$$

$$= 0,4891 \text{ ft}$$

b. Panjang Daun Pengaduk

$$L = \frac{d}{4}$$

$$L = \frac{0,1491 \text{ m}}{4}$$

$$L = 0,0373 \text{ m}$$

$$= 0,1223 \text{ ft}$$

c. Lebar Daun Pengaduk

$$W = \frac{d}{5}$$

$$W = \frac{0,1491 \text{ m}}{5}$$

$$W = 0,0298 \text{ m}$$

$$= 0,0978 \text{ ft}$$

d. Tinggi Pengaduk Dari Dasar Tangki

$$E = \frac{D_t}{3}$$

$$E = \frac{0{,}4474 \text{ m}}{3}$$

$E = 0{,}1491$ m

$= 0{,}4891$ ft

e. Lebar *Baffle*

$$J = \frac{D_t}{12}$$

$$J = \frac{0{,}4474 \text{ m}}{12}$$

$J = 0{,}0373$ m

$= 0{,}1223$ ft

f. Kecepatan Putar Pengaduk

Berdasarkan persamaan 6-18 *Robert Treyball-Mass Transfer Operation,* kecepatan putar pengaduk dapat dihitung dengan persamaan berikut.

Dengan $g_c = 32{,}2$ ft/s^2

σ = 72,75 dyn/cm (*Mc.cabe – Unit Operation Of Chemical Engineering 5th Page 274*).

= 0,0537 lb/ft

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

$$\frac{N_d}{\left(\frac{0{,}0537 \text{ lb/ft} \times 32{,}2 \text{ ft/s}^2}{73{,}6674 \text{ lb/ft}^3}\right)^{0,25}} = 1{,}22 + 1{,}25\ \left(\frac{1{,}4674 \text{ ft}}{0{,}4891 \text{ ft}}\right)$$

$N_d = 5{,}4419$ rps

g. Daya Pengadukan

Berdasarkan persamaan 9-17 *Mc.cabe – Unit Operation Of Chemical Engineering 5^{t},* bilangan *reynold* dapat dihitung dengan persamaan berikut.

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

$$N_{Re} = \frac{73{,}6674\ lb/ft^3 \times 5{,}4419\ rps \times (0{,}4891\ ft)^2}{0{,}0005\ lb/ft.s}$$

N_{Re} = 187.806,1655

Karena Nre > 10.000, maka berdasarkan persamaan 9.24 *Mc.cabe – Unit Operation Of Chemical Engineering 5^{t},* daya pengadukan menggunakan dapat dihitung dengan persamaan berikut.

Dengan K_T = 0,87 (*Mc. Cabe & Smith - Unit Operations Of Chemical Engineering 5th, Page 254*)

$$P = \frac{K_T N^3 D_a^5 \rho}{g_c}$$

$$P = \frac{0{,}87 \times (5{,}4419\ rps)^3 \times (0{,}4891\ ft)^5 \times 73{,}6674\ lb/ft^3}{32{,}2\ ft/s^2}$$

P = 8,9817 ft.lbf/s

P = 0,0163 HP

h. Daya Motor

Efisiensi Motor = 80%

$$\text{Daya Motor} = \frac{0{,}0163\ HP}{80\%}$$

Daya Motor = 0,0204 HP

≈ 0,5 HP

7) Tangki Koagulasi (CT-2061)

Fungsi : Tempat pembentukan flok-flok

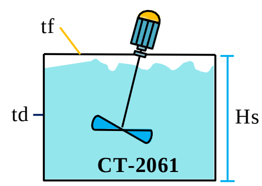
Tipe : Silinder vertikal dengan alas dan tutup datar

Bahan konstruksi : *Carbon steel 70 C-Si (SA-515 Grade 70)*

Jumlah : 1 unit

Sifat bahan : Tidak volatil, tidak korosif dan tidak higroskopis

Fasa : Cair



Gambar LC-41. Tangki Koagulasi

Data:

- Laju alir umpan : 45.977,4573 kg/jam : 101.361,9023 lb/jam
- Densitas campuran : 1.172,5000 kg/m^3 : 73,1992 lb/ft^3
- Tekanan : 1 atm
- Viskositas campuran : 1 cP : 0,0007 lb/ft.s
- Waktu koagulasi : 2 menit : 0,0300 jam

1. Kapasitas Tangki

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

$$V_p = \frac{45.977,4573 \text{ kg/jam} \times 0,0300 \text{ jam}}{1.172,5000 \text{ kg/m}^3}$$

$$V_p = 1,3071 \text{ m}^3$$

Dengan Mempertimbangkan faktor keamanan 20 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$V_p = 0{,}8\ V_t$

$V_t = \dfrac{V_p}{0{,}8}$

$V_t = \dfrac{1{,}3071\ m^3}{0{,}8}$

$V_t = 1{,}6339\ m^3$

2. Dimensi Tangki

a. Volume Silinder

$V_s = \dfrac{\pi}{4} \times D_t^{\,2} \times H_s$ Dengan $H_s = 1{,}5\ D_t$

$V_s = \dfrac{\pi}{4} \times 1{,}5\ D_t^{\,3}$

$V_s = 1{,}1775\ D_t^3$

b. Diameter Tangki

$V_t = V_s$

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

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

$D_t^3 = \dfrac{1{,}6339\ m^3}{1{,}1775}$

$D_t = \sqrt[3]{\dfrac{1{,}6339\ m^3}{1{,}1775}}$

$D_t = 1{,}1160$ m

= 3,6605 ft

= 43,9366 in

c. Tinggi Silinder

$H_s = 1{,}5\ D_t$

$H_s = 1{,}5 \times 1{,}1160$ m

$H_s = 1{,}6740$ m

$= 5{,}4907$ ft

$= 65{,}9049$ in

d. Tinggi Tangki

$H_t = H_s$

$H_t = 1{,}6740$ m

$H_t = 1{,}6740$ m

e. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s)}{V_t}$$

$$H_c = \frac{1{,}3071\ m^3 \times (1{,}6760\ m)}{1{,}6339\ m^3}$$

$H_c = 1{,}3392$ m

$= 4{,}3925$ ft

$= 52{,}7240$ in

f. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

$P_c = 1.172{,}5000\ kg/m^3 \times 9{,}81\ m/s^2 \times 1{,}3392$ m

$P_c = 15.403{,}6773\ kg.m/s^2$

$= 0{,}1494$ atm

$= 2{,}1958$ psi

g. Tekanan Desain

$P_d = P_{op} + P_c$

P_d = 1 atm + 0,1494 atm

P_d = 1,1494 atm

= 16,8917 psi

P_d = 16,8917 psi

R = 21,9683 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

h. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{16,8917 \text{ psi} \times 21,9683 \text{ in}}{17500 \text{ psi} \times 0,85 - 0,6 \times 16,8917 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2250 in

= 0,0057 m

$= 0{,}0187$ ft

$= 5{,}7141$ mm

i. Tebal Alas Tangki

$t_f = D\sqrt{\frac{0{,}3\ P}{S}} + C$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$t_f = 43{,}9366\ in\sqrt{\frac{0{,}3 \times 16{,}8917\ psi}{17500\ psi}} + 0{,}02\ in/tahun \times 10\ tahun = 0{,}2190\ in$

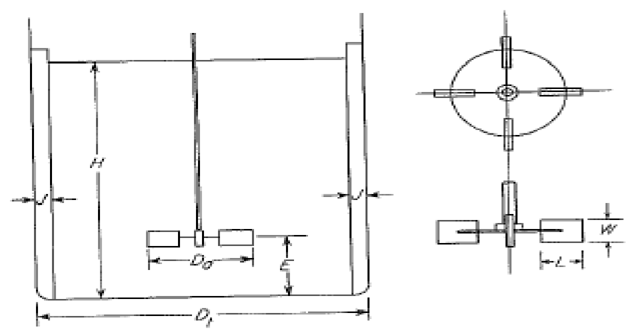
$= 0{,}0056$ m

$= 0{,}0182$ ft

$= 5{,}5624$ mm

3. Desain Pengaduk

Viskositas umpan < 4000 cP, maka dipilih *propeller* berdaun tiga (Kecepatan 1800 rpm) (*Walas - Selection Design & Chemical Process Equipment ed 1st, Page 288*).



Gambar LC-42. Desain Pengaduk Tangki Koagulasi

a. Diameter Pengaduk

$d = \frac{D_t}{3}$

$d = \frac{1{,}1160\ m}{3}$

$d = 0{,}3720 \text{ m}$

$\quad = 1{,}2202 \text{ ft}$

b. Panjang Daun Pengaduk

$$L = \frac{d}{4}$$

$$L = \frac{0{,}3720 \text{ m}}{4}$$

$L = 0{,}0930 \text{ m}$

$\quad = 0{,}3050 \text{ ft}$

c. Lebar Daun Pengaduk

$$W = \frac{d}{5}$$

$$W = \frac{0{,}3720 \text{ m}}{5}$$

$W = 0{,}0744 \text{ m}$

$\quad = 0{,}2440 \text{ ft}$

d. Tinggi Pengaduk Dari Dasar Tangki

$$E = \frac{D_t}{3}$$

$$E = \frac{1{,}1160 \text{ m}}{3}$$

$E = 0{,}3720 \text{ m}$

$\quad = 1{,}2202 \text{ ft}$

e. Lebar *Baffle*

$$J = \frac{D_t}{12}$$

$$J = \frac{1,1160 \text{ m}}{12}$$

$J = 0,0930$ m

$= 0,3050$ ft

f. Kecepatan Putar Pengaduk

Berdasarkan persamaan 6-18 *Robert Treyball-Mass Transfer Operation,* kecepatan putar pengaduk dapat dihitung dengan persamaan berikut.

Dengan $g_c = 32,2$ ft/s^2

σ = 72,75 dyn/cm (*Mc.cabe – Unit Operation Of Chemical Engineering 5th Page 274*).

= 0,0537 lb/ft

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

$$\frac{N_d}{\left(\frac{0,0537 \text{ lb/ft} \times 32,2 \text{ ft/s}^2}{73,1992 \text{ lb/ft}^3}\right)^{0,25}} = 1,22 + 1,25 \left(\frac{3,6605 \text{ ft}}{1,2202 \text{ ft}}\right)$$

$N_d = 2,1835$ rps

g. Daya Pengadukan

Berdasarkan persamaan 9-17 *Mc.cabe – Unit Operation Of Chemical Engineering 5^t,* bilangan *reynold* dapat dihitung dengan persamaan berikut.

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

$$N_{Re} = \frac{73,1992 \text{ lb/ft}^3 \times 2,1835 \text{ rps} \times (1,2202 \text{ ft})^2}{0,0007 \text{ lb/ft.s}}$$

$N_{Re} = 354.086,1006$

Karena Nre > 10.000, maka berdasarkan persamaan 9.24 *Mc.cabe – Unit Operation Of Chemical Engineering 5^t^*, daya pengadukan menggunakan dapat dihitung dengan persamaan berikut.

Dengan K_T = 0,87 (*Mc. Cabe & Smith - Unit Operations Of Chemical Engineering 5th, Page 254*)

$$P = \frac{K_T N^3 D_a^5 \rho}{g_c}$$

$$P = \frac{0,87 \times (2,1835 \text{ rps})^3 \times (1,2202 \text{ ft})^5 \times 73,1992 \text{ lb/ft}^3}{32,2 \text{ ft/s}^2}$$

P = 55,6765 ft.lbf/s

P = 0,1012 HP

h. Daya Motor

Efisiensi Motor = 80%

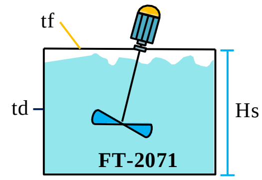
$$\text{Daya Motor} = \frac{0,1012 \text{ HP}}{80\%}$$

Daya Motor = 0,1265 HP

≈ 0,5 HP

8) Tangki Flokulasi (FT-2071)

Fungsi	: Tempat pembentukan makro flok
Tipe	: Silinder vertikal dengan alas dan tutup datar
Bahan konstruksi	: *Carbon steel 70 C-Si (SA-515 Grade 70)*
Jumlah	: 1 unit
Sifat bahan	: Tidak volatil, tidak korosif dan tidak higroskopis
Fasa	: Cair



Gambar LC-43. Tangki Flokulasi

Data:

- Laju alir umpan : 46.176,1747 kg/jam : 101.799,9947 lb/jam
- Densitas campuran : 1.172,5000 kg/m^3 : 73,1992 lb/ft^3
- Tekanan : 1 atm
- Viskositas campuran : 1 cP : 0,0007 lb/ft.s
- Waktu koagulasi : 2 menit : 0,0300 jam

1. Kapasitas Tangki

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

$$V_p = \frac{45.977{,}4573 \text{ kg/jam} \times 0{,}0300 \text{ jam}}{1.172{,}5000 \text{ kg/m}^3}$$

$$V_p = 1{,}3071 \text{ m}^3$$

Dengan Mempertimbangkan faktor keamanan 20 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$$V_p = 0{,}8\ V_t$$

$$V_t = \frac{V_p}{0{,}8}$$

$$V_t = \frac{1{,}3071 \text{ m}^3}{0{,}8}$$

$$V_t = 1{,}6339 \text{ m}^3$$

2. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1,1775\ D_t^3$

b. Diameter Tangki

$V_t = V_s$

$V_t = 1,1775\ D_t^3$

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

$D_t^3 = \frac{1,6339\ m^3}{1,1775}$

$D_t = \sqrt[3]{\frac{1,6339\ m^3}{1,1775}}$

$D_t = 1,1160$ m

= 3,6605 ft

= 43,9366 in

c. Tinggi Silinder

$H_s = 1,5\ D_t$

$H_s = 1,5 \times 1,1160$ m

$H_s = 1,6740$ m

= 5,4907 ft

= 65,9049 in

d. Tinggi Tangki

$H_t = H_s$

$H_t = 1{,}6740$ m

$H_t = 1{,}6740$ m

e. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s)}{V_t}$$

$$H_c = \frac{1{,}3071\ m^3 \times (1{,}6760\ m)}{1{,}6339\ m^3}$$

$H_c = 1{,}3392$ m

= 4,3925 ft

= 52,7240 in

f. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

$P_c = 1.172{,}5000\ kg/m^3 \times 9{,}81\ m/s^2 \times 1{,}3392$ m

$P_c = 15.403{,}6773\ kg.m/s^2$

= 0,1494 atm

= 2,1958 psi

g. Tekanan Desain

$P_d = P_{op} + P_c$

$P_d = 1$ atm + 0,1494 atm

$P_d = 1{,}1494$ atm

= 16,8917 psi

P_d = 16,8917 psi

R = 21,9683 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

h. Tebal Dinding Tangki

$$t_d = \frac{PR}{SE - 0{,}6P} + C$$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{16{,}8917 \text{ psi} \times 21{,}9683 \text{ in}}{17500 \text{ psi} \times 0{,}85 - 0{,}6 \times 16{,}8917 \text{ psi}} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2250 in

= 0,0057 m

= 0,0187 ft

= 5,7141 mm

i. Tebal Alas Tangki

$$t_f = D\sqrt{\frac{0{,}3\ P}{S}} + C$$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$$t_f = 43,9366 \text{ in} \sqrt{\frac{0,3 \times 16,8917 \text{ psi}}{17500 \text{ psi}}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun} = 0,2190 \text{ in}$$

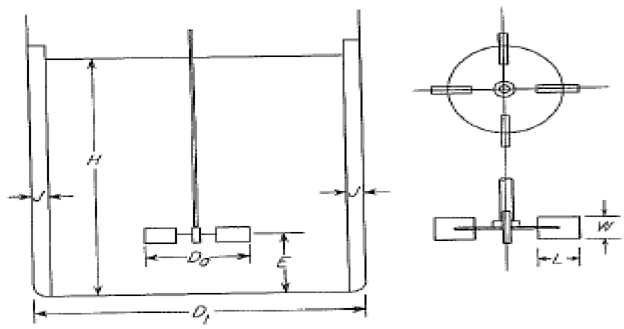
$$= 0,0056 \text{ m}$$

$$= 0,0182 \text{ ft}$$

$$= 5,5624 \text{ mm}$$

4. Desain Pengaduk

Viskositas umpan < 4000 cP, maka dipilih *propeller* berdaun tiga (Kecepatan 1800 rpm) (*Walas - Selection Design & Chemical Process Equipment ed 1st, Page 288*).



Gambar LC-42. Desain Pengaduk Tangki Koagulasi

a. Diameter Pengaduk

$$d = \frac{D_t}{3}$$

$$d = \frac{1,1160 \text{ m}}{3}$$

$$d = 0,3720 \text{ m}$$

$$= 1,2202 \text{ ft}$$

b. Panjang Daun Pengaduk

$$L = \frac{d}{4}$$

$$L = \frac{0,3720 \text{ m}}{4}$$

L = 0,0930 m

= 0,3050 ft

c. Lebar Daun Pengaduk

$$W = \frac{d}{5}$$

$$W = \frac{0,3720 \text{ m}}{5}$$

W = 0,0744 m

= 0,2440 ft

d. Tinggi Pengaduk Dari Dasar Tangki

$$E = \frac{D_t}{3}$$

$$E = \frac{1,1160 \text{ m}}{3}$$

E = 0,3720 m

= 1,2202 ft

e. Lebar *Baffle*

$$J = \frac{D_t}{12}$$

$$J = \frac{1,1160 \text{ m}}{12}$$

J = 0,0930 m

= 0,3050 ft

f. Kecepatan Putar Pengaduk

Berdasarkan persamaan 6-18 *Robert Treyball-Mass Transfer Operation,* kecepatan putar pengaduk dapat dihitung dengan persamaan berikut.

Dengan $g_c = 32{,}2 \text{ ft/s}^2$

σ = 72,75 dyn/cm (*Mc.cabe – Unit Operation Of Chemical Engineering 5^th^ Page 274*).

= 0,0537 lb/ft

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

$$\frac{N_d}{\left(\frac{0{,}0537 \text{ lb/ft} \times 32{,}2 \text{ ft/s}^2}{73{,}1992 \text{ lb/ft}^3}\right)^{0,25}} = 1{,}22 + 1{,}25\ \left(\frac{3{,}6605 \text{ ft}}{1{,}2202 \text{ ft}}\right)$$

$$N_d = 2{,}1835 \text{ rps}$$

g. Daya Pengadukan

Berdasarkan persamaan 9-17 *Mc.cabe – Unit Operation Of Chemical Engineering 5^t^,* bilangan *reynold* dapat dihitung dengan persamaan berikut.

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

$$N_{Re} = \frac{73{,}1992 \text{ lb/ft}^3 \times 2{,}1835 \text{ rps} \times (1{,}2202 \text{ ft})^2}{0{,}0007 \text{ lb/ft.s}}$$

N_{Re} = 354.086,1006

Karena Nre > 10.000, maka berdasarkan persamaan 9.24 *Mc.cabe – Unit Operation Of Chemical Engineering 5^t^,* daya pengadukan menggunakan dapat dihitung dengan persamaan berikut.

Dengan K_T = 0,87 (*Mc. Cabe & Smith - Unit Operations Of Chemical Engineering 5th, Page 254*)

$$P = \frac{K_T N^3 D_a^5 \rho}{g_c}$$

$$P = \frac{0{,}87 \times (2{,}1835\ \text{rps})^3 \times (1{,}2202\ \text{ft})^5 \times 73{,}1992\ \text{lb/ft}^3}{32{,}2\ \text{ft/s}^2}$$

P = 55,6765 ft.lbf/s

P = 0,1012 HP

h. Daya Motor

Efisiensi Motor = 80%

$$\text{Daya Motor} = \frac{0{,}1012\ \text{HP}}{80\%}$$

Daya Motor = 0,1265 HP

≈ 0,5 HP

9) Tangki Sedimentasi (ST-2081)

Fungsi : Tempat mengendapkan makro flok

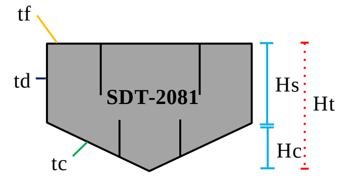
Tipe : Silinder vertikal dengan alas *conical* dan tutup datar

Bahan konstruksi : *Carbon steel 70 C-Si (SA-515 Grade 70)*

Jumlah : 1 unit

Sifat bahan : Tidak volatil, tidak higroskopis dan tidak korosif

Fasa : Cair



Gambar LC-45. Tangki Sedimentasi

Data:

- Laju alir umpan : 45.977,4573 kg/jam : 101.361,9023 lb/jam
- Densitas campuran : 1.172,5000 kg/m^3 : 73,1992 lb/ft^3
- Tekanan : 1 atm
- Viskositas campuran : 1 cP : 0,0007 lb/ft.s
- Waktu pengendapan : 5 menit : 0,0833 jam

1. Kapasitas Tangki

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

$$V_p = \frac{45.977,4573 \text{ kg/jam} \times 0,0833 \text{ jam}}{1.172,5000 \text{ kg/m}^3}$$

$$V_p = 3,2678 \text{ m}^3$$

Dengan Mempertimbangkan faktor keamanan 10 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$$V_p = 0,9 V_t$$

$$V_t = \frac{V_p}{0,9}$$

$$V_t = \frac{3,2678 \text{ m}^3}{0,9}$$

$$V_t = 3,6309 \text{ m}^3$$

2. Dimensi Tangki

a. Volume Silinder

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

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

$$V_s = 1,1775 D_t^3$$

b. Volume *Conical*

$V_c = \frac{\pi}{6} \times D_t^2 \times H_c$ Dengan $H_c = 1/2\ D_t \tan 45°$ (*Table 18.4, Chemical Process Equipment*, S. Walas, Page 658)

$V_c = 0{,}2617\ D_t^3$

c. Diameter Tangki

$V_t = V_s + V_c$

$V_t = 1{,}1775\ D_t^3 + 0{,}2617\ D_t^3$

$V_t = 1{,}4392\ D_t^3$

$D_t^3 = \frac{V_t}{1{,}4392}$

$D_t^3 = \frac{3{,}6309\ m^3}{1{,}4392}$

$D_t = \sqrt[3]{\frac{3{,}6309\ m^3}{1{,}4392}}$

$D_t = 1{,}3609$ m

= 4,4638 ft

= 53,5793 in

d. Tinggi Silinder

$H_s = 1{,}5\ D_t$

$H_s = 1{,}5 \times 1{,}3609$ m

$H_s = 2{,}0414$ m

= 6,6957 ft

= 80,3690 in

e. Tinggi *Conical*

$H_c = 1/2\ D_t \tan 45°$

H_c = 1/2 × 1,3609 m × 1

H_c = 0,6805 m

= 2,2319 ft

= 26,7897 in

f. Tinggi Tangki

$H_t = H_s + H_c$

H_t = 2,0414 m + 0,6805 m

H_t = 2,7218 m

P_d = 14,7 psi

R = 26,7897 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

g. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{14,7 \text{ psi} \times 26,7897 \text{ in}}{17500 \text{ psi} \times 0,85 - 0,6 \times 14,7 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2265 in

= 0,0058 m

= 0,0189 ft

= 5,7529 mm

h. Tebal Dinding *Conical*

$$t_c = \frac{PD}{2(SE - 0,2P)\cos 30°} + C$$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_c = \frac{14,7 \text{ psi} \times 53,5793 \text{ in}}{2(17500 \text{ psi} \times 0,85 - 0,2 \times 14,7 \text{ psi})0,71} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_c = 0,2373 in

= 0,0060 m

= 0,0198 ft

= 6,0275 mm

i. Tebal Tutup Tangki

$$t_f = D\sqrt{\frac{0,3 P}{S}} + C$$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$$t_f = 53,5793 \text{ in}\sqrt{\frac{0,3 \times 14,7 \text{ psi}}{17500 \text{ psi}}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun} = 1,0505 \text{ in}$$

= 0,0267 m

= 0,0875 ft

= 26,6839 mm

10) *Sand Filter* (SF-3091)

Fungsi : Tempat menyaring sisa-sisa flok

Tipe : Silinder vertikal dengan alas dan tutup *elipsoidal*

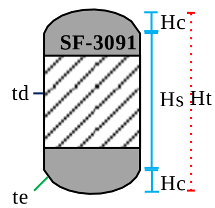
Bahan konstruksi : *Carbon steel 70 C-Si (SA-515 Grade 70)*

Jumlah : 2 unit

Sifat bahan : Tidak volatil, tidak korosif dan tidak higroskopis

Fasa : Cair

Media filter : Pasir silika



Gambar LC-46. *Sand Filter*

Data:

- Laju alir umpan : 22.984,477 kg/jam
- Densitas campuran : 1.000 kg/m^3 : 62,4300 lb/ft^3
- Tekanan : 1 atm
- Viskositas campuran : 1 cP : 0,0007 lb/ft.s
- Waktu tinggal : 15 menit : 0,25 jam
- Volume pasir : 85%

1. Volume Air

$$V_a = \frac{\text{laju alir} \times \text{waktu tinggal}}{\rho}$$

$$V_a = \frac{22.984,477\ \frac{kg}{jam} \times 0,25\ jam}{1.000\ kg/m^3} = 5,7461\ m^3$$

2. Kondisi filter

Porositas unggun = 0,4

Air yang terisi dalam unggun = 60% dari air masuk

= 3,4477 m^3

Sehingga, volume padatan = 85% dari air masuk

= 4,8842 m^3

$$\text{Volume unggun} = \frac{\text{V air yang mengisi unggun}}{\text{V padatan}} = 8{,}3319\ m^3$$

3. Kapasitas Tangki

V_p = volume unggun + volume air

$V_p = 8{,}3319\ m^3 + 5{,}7461\ m^3$

$V_p = 14{,}0780\ m^3$

Dengan Mempertimbangkan faktor keamanan 10 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$V_p = 0{,}9\ V_t$

$$V_t = \frac{V_p}{0{,}9}$$

$$V_t = \frac{14{,}0780\ m^3}{0{,}9}$$

$V_t = 15{,}6422\ m^3$

4. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1{,}1775\ D_t^3$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0{,}1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + 2\ V_e$

$V_t = 1{,}1775\ D_t^3 + 2\ (0{,}1308\ D_t^3)$

$V_t = 1{,}4391\ D_t^3$

$$D_t^3 = \frac{V_t}{1{,}4391}$$

$$D_t^3 = \frac{15{,}6422\ m^3}{1{,}4391}$$

$$D_t = \sqrt[3]{\frac{15{,}6422\ m^3}{1{,}4391}}$$

$D_t = 2{,}2134$ m

= 7,2599 ft

= 87,1410 in

d. Tinggi Silinder

$H_s = 1{,}5\ D_t$

$H_s = 1{,}5 \times 2{,}2134$ m

$H_s = 3{,}3201$ m

= 10,8899 ft

= 130,7115 in

e. Tinggi *Ellipsoidal*

H_e = 1/4 D_t

H_e = 1/4 × 2,2134 m

H_e = 0,5533 m

= 1,8150 ft

= 21,7852 in

f. Tinggi Tangki

H_t = H_s + (2 H_e)

H_t = 3,3201 m + (2 × 0,5533 m)

H_t = 4,4268 m

P_d = 14,6959 psi

R = 43,5705 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

g. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0{,}6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{14{,}6959 \text{ psi} \times 43{,}5705 \text{ in}}{17500 \text{ psi} \times 0{,}85 - 0{,}6 \times 14{,}6959 \text{ psi}} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2431 in

= 0,0062 m

= 0,0203 ft

= 6,1740 mm

h. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0{,}2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{14{,}6959 \text{ psi} \times 87{,}1410 \text{ in}}{2 \times 17500 \text{ psi} \times 0{,}85 - 0{,}2 \times 14{,}6959 \text{ psi}} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2431 in

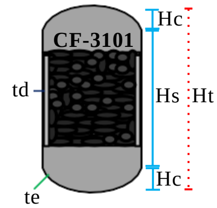
= 0,0062 m

= 0,0203 ft

= 6,1735 mm

11) *Carbon Filter* (CF-3101)

Fungsi	: Tempat menyaring sisa-sisa flok serta mengurangi warna dan bau pada air.
Tipe	: Silinder vertikal dengan alas dan tutup *elipsoidal*
Bahan konstruksi	: *Carbon steel 70 C-Si (SA-515 Grade 70)*
Jumlah	: 2 unit
Sifat bahan	: Tidak volatil, tidak korosif dan tidak higroskopis
Fasa	: Cair
Media filter	: Karbon aktif



Gambar LC-47. *Carbon Filter*

Data:

- Laju alir umpan : 23.083,817 kg/jam : lb/jam
- Densitas campuran : 1.000 kg/m^3 : 62,4300 lb/ft^3
- Tekanan : 1 atm
- Viskositas campuran : 1 cP : 0,0007 lb/ft.s
- Waktu tinggal : 15 menit : 0,25 jam
- Volume *carbon* aktif : 85% Laju alir umpan : 22.984,477 kg/jam
- Densitas campuran : 1.000 kg/m^3 : 62,4300 lb/ft^3
- Tekanan : 1 atm
- Viskositas campuran : 1 cP : 0,0007 lb/ft.s
- Waktu tinggal : 15 menit : 0,25 jam
- Volume pasir : 85%

1. Volume Air

$$V_a = \frac{\text{laju alir} \times \text{waktu tinggal}}{\rho}$$

$$V_a = \frac{22.984,477\ \frac{kg}{jam} \times 0,25\ jam}{1.000\ kg/m^3} = 5,7461\ m^3$$

2. Kondisi filter

Porositas unggun = 0,4

Air yang terisi dalam unggun = 60% dari air masuk

= $3{,}4477\ m^3$

Sehingga, volume padatan = 85% dari air masuk

= $4{,}8842\ m^3$

$$\text{Volume unggun} = \frac{\text{V air yang mengisi unggun}}{\text{V padatan}} = 8{,}3319\ m^3$$

3. Kapasitas Tangki

V_p = volume unggun + volume air

$V_p = 8{,}3319\ m^3 + 5{,}7461\ m^3$

$V_p = 14{,}0780\ m^3$

Dengan Mempertimbangkan faktor keamanan 10 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$V_p = 0{,}9\ V_t$

$$V_t = \frac{V_p}{0{,}9}$$

$$V_t = \frac{14{,}0780\ m^3}{0{,}9}$$

$V_t = 15{,}6422\ m^3$

4. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1{,}1775\ D_t^3$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0{,}1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + 2\ V_e$

$V_t = 1{,}1775\ D_t^3 + 2\ (0{,}1308\ D_t^3)$

$V_t = 1{,}4391\ D_t^3$

$D_t^3 = \frac{V_t}{1{,}4391}$

$D_t^3 = \frac{15{,}6422\ m^3}{1{,}4391}$

$D_t = \sqrt[3]{\frac{15{,}6422\ m^3}{1{,}4391}}$

$D_t = 2{,}2134$ m

= 7,2599 ft

= 87,1410 in

d. Tinggi Silinder

$H_s = 1{,}5\ D_t$

$H_s = 1{,}5 \times 2{,}2134$ m

$H_s = 3{,}3201$ m

= 10,8899 ft

= 130,7115 in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

H_e = 1/4 × 2,2134 m

H_e = 0,5533 m

= 1,8150 ft

= 21,7852 in

f. Tinggi Tangki

$H_t = H_s + (2\ H_e)$

H_t = 3,3201 m + (2 × 0,5533 m)

H_t = 4,4268 m

P_d = 14,6959 psi

R = 43,5705 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

g. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{14{,}6959 \text{ psi} \times 43{,}5705 \text{ in}}{17500 \text{ psi} \times 0{,}85 - 0{,}6 \times 14{,}6959 \text{ psi}} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2431 in

= 0,0062 m

= 0,0203 ft

= 6,1740 mm

h. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0{,}2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{14{,}6959 \text{ psi} \times 87{,}1410 \text{ in}}{2 \times 17500 \text{ psi} \times 0{,}85 - 0{,}2 \times 14{,}6959 \text{ psi}} + 0{,}02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2431 in

= 0,0062 m

= 0,0203 ft

= 6,1735 mm

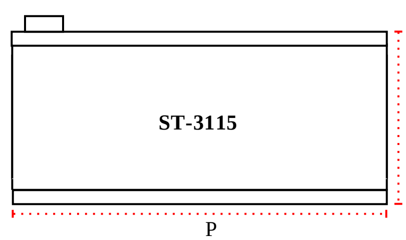
12) Bak Penampung Air Bersih (ST-3115)

Fungsi : Menampung air bersih hasil penyaringan *carbon filter*

Tipe : Persegi panjang

Bahan konstruksi : Beton bertulang

Jumlah : 2 unit



Gambar LC-48. Bak Penampung Air Bersih

Data:

- Laju alir umpan : 45.968,9530 kg/jam
- Laju alir volumetrik : 45,9690 m^3/jam
- Densitas campuran : 1.000 kg/m^3
- Lama penyimpanan : 24 jam
- Tekanan : 1 atm
- Temperatur : 30 ^oC

$$V = Q \times t$$

$$V = 45{,}9690 \frac{m^3}{jam} \times 24 \text{ jam} = 1.103{,}2549 \text{ m}^3$$

Direncanakan akan digunakan 2 unit bak, sehingga kapasitas asing-masing adalah

$$V = 1.103{,}2549 \text{ m}^3/2 = 551{,}6274 \text{ m}^3$$

Faktor keamanan = 20%

$$V_p = \frac{V}{0{,}8}$$

$$V_p = \frac{551{,}6274 \text{ m}^3}{0{,}8} = 689{,}5343 \text{ m}^3$$

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

$$V = P \times L \times T$$

$$689{,}5343 \text{ m} = 3T \times 2T \times T$$

$$6T^3 = 689{,}5343 \text{ m}$$

$$T = \sqrt[3]{\frac{689{,}5343 \text{ m}}{6}} = 4{,}8542 \text{ m}$$

$$P = 3T$$

$$P = 3 \times 4{,}8542 \text{ m} = 14{,}5625 \text{ m}$$

L = 2T

L = 2 × 4,8542 m = 9,7083 m

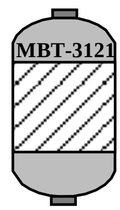
13) *Mix Bed Ion Exchange* (MBT-3121)

Fungsi : Tempat pertukaran kation dan anion dalam air

Tipe : MHC-2400-3

Bahan konstruksi : *Carbon steel 70 C-Si (SA-515 Grade 70)*

Jumlah : 2 unit



Gambar LC-49. *Mix Bed Ion Exchange*

Data:

- Laju alir umpan : 22.178,6435 kg/jam
- Densitas campuran : 1.000 kg/m^3
- Tekanan : 1 atm
- Temperatur : 30 ^oC

1. Kapasitas Tangki

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

$$V_p = \frac{22.178{,}6435 \text{ kg/jam}}{1.000 \text{ kg/m}^3}$$

$$V_p = 22{,}1786 \text{ m}^3\text{/jam}$$

Dengan Mempertimbangkan faktor keamanan 10 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$V_p = 0{,}9\ V_t$

$$V_t = \frac{V_p}{0{,}9}$$

$$V_t = \frac{22{,}1786\ m^3/jam}{0{,}9}$$

V_t = 24,6429 m^3/jam

V_t = 870,2407 ft^3/jam

V_t = 108,4996 gal/menit

Berdasarkan data kapasitas tersebut, maka dipilih alat *mix bed ion exchange* dengan spesifikasi sebagai berikut.

Laju alir max	= 120 GPM
Ukuran pipa *in*	= 3 in
Ukuran pipa *out*	= 3 in
Volume resin	= 80 ft^3
Diameter tangki	= 66 in
Tinggi tangki	= 72 in

Specifications

CATALOG NUMBER	EXCHANGE CAPACITY (Grains) SALT USAGE (LBS) ❶		FLOW RATES			PIPE SIZE		RESIN	TANK SIZES		SALT STORAGE	REGEN PER SALT REFILL		OVERALL DIMENSIONS (INCHES) ❹			SHIPPING WEIGHT (LBS) ❺		
			SERVICE		BACK WASH	SERVICE	DRAIN		SOFTENER	BRINE									
	MAX. SALT	MIN. SALT	CONT. GPM ❷	PEAK GPM ❸	GPM	INCHES	INCHES	CU. FT.	INCHES	INCHES	LBS	MIN. SALT	MAX. SALT	SINGLE (L1xWxH)	TWIN (L2xWxH)	TRIPLE (L3xWxH)	SINGLE	TWIN	TRIPLE
MHC-1200-3	1,200,000 600	800,000 240	215	300	60	3	2	40	48 x 60	52 x 60	2600	10	4	120x64x98	188x64x98	252x64x98	5,700	10,800	15,900
MHC-1200-4			310	410		4	2							120x68x98	188x68x98	252x68x98	5,730	10,860	16,000
MHC-1500-3	1,500,000 750	1,000,000 300	225	308	80	3	2	50	54 x 60	66 x 46	3300	11	4	140x70x100	214x70x100	288x70x100	6,850	13,050	19,100
MHC-1500-4			405	600		4	2							140x74x100	214x74x100	288x74x100	6,880	13,110	19,200
MHC-1950-3	1,950,000 975	1,300,000 390	235	325	100	3	2	65	60 x 60	72 x 46	4000	10	4	158x76x102	232x76x102	312x76x102	8,500	16,200	23,950
MHC-1950-4			445	650		4	2							158x80x102	232x80x102	312x80x102	8,550	16,250	24,000
MHC-2400-3	2,400,000 1,200	1,600,000 480	245	340	120	3	3	80	66 x 72	84 x 46	6100	12	5	170x84x114	256x84x114	342x84x114	10,700	20,500	30,300
MHC-2400-4			480	690		4	3							170x86x114	256x86x114	342x86x114	10,750	20,600	30,500
MHC-2400-6			660	940		6	3							170x92x114	256x92x114	342x92x114	10,800	20,700	30,700
MHC-3000-3	3,000,000 1,500	2,000,000 600	255	355	140	3	3	100	72 x 72	82 x 60	7600	12	5	174x88x117	266x88x117	358x88x117	12,300	23,600	34,900
MHC-3000-4			500	720		4	3							174x92x117	266x92x117	358x92x117	12,350	23,700	35,100
MHC-3000-6			700	1050		6	3							174x96x117	266x96x117	358x96x117	12,400	23,800	35,300
MHC-4200-4	4,200,000 2,100	2,800,000 840	540	760	190	4	3	140	84 x 72	90 x 60	8600	10	4	194x104x120	298x104x120	402x104x120	16,100	30,900	45,700
MHC-4200-6			780	1130		6	3							194x110x120	298x110x120	402x110x120	16,250	31,200	45,900
MHC-4200-8			1000	1450		8	3							194x118x120	298x118x120	402x118x120	16,300	31,300	46,150
MHC-5400-4	5,400,000 2,700	3,600,000 1,080	675	820	250	4	4	180	96 x 72	90 x 60	8000	7	3	206x116x123	322x116x123	438x116x123	21,475	41,600	61,650
MHC-5400-6			880	1250		6	4							206x122x123	322x122x123	438x122x123	21,600	41,800	61,800
MHC-5400-8			1150	1700		8	4							206x134x123	322x134x123	438x134x123	21,700	41,950	62,950

Marlo incorporated catalogue

14) Tangki Air Demin (ST-3136)

Fungsi : Tempat menyimpan air bebas mineral/*demin water*

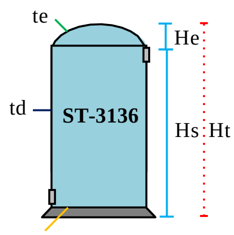
Tipe : Silinder vertikal dengan alas datar dan tutup *elipsoidal*

Bahan konstruksi : *Carbon steel 70 C-Si (SA-515 Grade 70)*

Jumlah : 1 unit

Sifat bahan : Tidak volatil, tidak korosif dan tidak higroskopis

Fasa : Cair



Gambar LC-50. Tangki Air Demin

Data:

- Laju alir umpan : 22.178,6435 kg/jam : 48.895,0375 lb/jam
- Densitas campuran : 1.000 kg/m^3
- Tekanan : 1 atm
- Viskositas Campuran : 1 cP : 0,0007 lb/ft.s
- Waktu Penyimpanan : 60 menit : 1 jam

1. Kapasitas Tangki

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

$$V_p = \frac{22.178,6435 \text{ kg/jam} \times 1 \text{ jam}}{1.000 \text{ kg/m}^3}$$

$$V_p = 22,1786 \text{ m}^3$$

Dengan Mempertimbangkan faktor keamanan 20 % (*Plant Design And Economics For Chemical Engineers Ed 4th, Peters, Page 37*).

$V_p = 0,9\ V_t$

$V_t = \frac{V_p}{0,9}$

$V_t = \frac{22,1786\ m^3}{0,9}$

$V_t = 24,6429\ m^3$

2. Dimensi Tangki

a. Volume Silinder

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

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

$V_s = 1,1775\ D_t^3$

b. Volume *Ellipsoidal*

$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$ Dengan $H_e = 1/4\ D_t$ (*Table 18.4*, *Chemical Process Equipment*, S. Walas, Page 658)

$V_e = 0,1308\ D_t^3$

c. Diameter Tangki

$V_t = V_s + 2\ V_e$

$V_t = 1,1775\ D_t^3 + 2\ (0,1308\ D_t^3)$

$V_t = 1,4391\ D_t^3$

$D_t^3 = \frac{V_t}{1,4391}$

$$D_t^3 = \frac{24,6429 \text{ m}^3}{1,4391}$$

$$D_t = \sqrt[3]{\frac{24,6429 \text{ m}^3}{1,4391}}$$

D_t = 2,6581 m

= 8,7185 ft

= 104,6491 in

d. Tinggi Silinder

$H_s = 1,5\ D_t$

$H_s = 1,5 \times 2,6581$ m

H_s = 3,9871 m

= 13,0778 ft

= 156,9736 in

e. Tinggi *Ellipsoidal*

$H_e = 1/4\ D_t$

$H_e = 1/4 \times 2,6581$ m

H_e = 0,6645 m

= 2,1796 ft

= 26,1623 in

f. Tinggi Tangki

$H_t = H_s + H_e$

H_t = 3,9871 m + 0,6645 m

H_t = 4,6517 m

g. Tinggi Cairan

$$H_c = \frac{V_p \times (H_s + (H_e))}{V_t}$$

$$H_c = \frac{22{,}1786\ m^3 \times (3{,}9871\ m + (0{,}6645\ m))}{24{,}6429\ m^3}$$

H_c = 4,1865 m

= 13,7317 ft

= 164,8223 in

h. Tekanan Hidrostatik

$P_c = \rho \times g \times H_c$

P_c = 1.000 kg/m^3× 9,81 m/s^2 × 4,1865 m

P_c = 41.069,5187 kg.m/s^2

= 0,3984 atm

= 5,8545 psi

i. Tekanan Desain

$P_d = P_{op} + P_c$

P_d = 1 atm + 0,3984 atm

P_d = 1,3984 atm

= 20,5504 psi

P_d = 20,5504 psi

R = 52,3245 in

S = 17500 psi (*Peters - Plant Design & Economics for Chemical Engineering, Tabel 4*)

E = 0,85 (Walas - *Chemical Process Equipment*, Table 18.5, Page 659)

C = 0,02 in/tahun (*Perry's ed 6th – Handbook Of Chemical Engineering, Table 23-2*)

Tahun digunakan = 10 tahun

Ket :

P_d = Tekanan Desain (psi)

R = Jari-jari (in)

S = allowable stress (psi)

E = Joint efficiency

C = Corrosion Factor (in/tahun)

j. Tebal Dinding Tangki

$t_d = \frac{PR}{SE - 0,6P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_d = \frac{20,5504 \text{ psi} \times 52,3245 \text{ in}}{17500 \text{ psi} \times 0,85 - 0,6 \times 20,5504 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_d = 0,2723 in

= 0,0069 m

= 0,0227 ft

= 6,9176 mm

k. Tebal Dinding *Ellipsoidal*

$t_e = \frac{PD}{2SE - 0,2P} + C$ (*Walas - Chemical Process Equipment, Table 18.4, Page 658*)

$$t_e = \frac{20,5504 \text{ psi} \times 104,6491 \text{ in}}{2 \times 17500 \text{ psi} \times 0,85 - 0,2 \times 20,5504 \text{ psi}} + 0,02 \text{ in/tahun} \times 10 \text{ tahun}$$

t_e = 0,2723 in

= 0,0069 m

= 0,0227 ft

= 6,9176 mm

l. Tebal Alas Tangki

$t_f = D\sqrt{\frac{0,3\ P}{S}} + C$ Walas - Chemical Process Equipment, Table 18.4, Page 658

$t_f = 104,6491\ in\sqrt{\frac{0,3 \times 20,5504\ psi}{17500\ psi}} + 0,02\ in/tahun \times 10\ tahun = 2,1672\ in$

= 0,0550 m

= 0,1803 ft

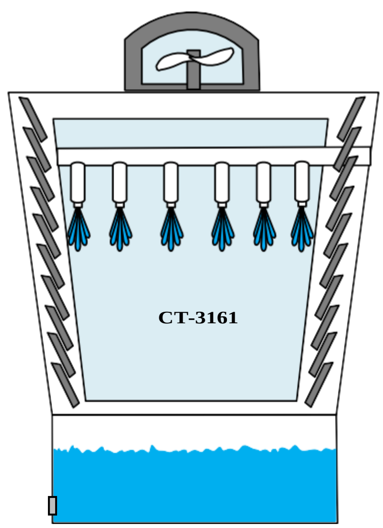
= 54,9708 mm

15) *Cooling Tower* (CT-3161)

Fungsi : Mendinginkan air sirkulasi yang telah dipakai sebagai media pendingin

Tipe : *Induced draft cooling tower*

Jumlah : 1 unit



Gambar LC-51. *Cooling Tower*

Data:

- Laju alir umpan : 40.556,3000 kg/jam : 89.410,4190 lb/jam
- Densitas campuran : 1.000 kg/m^3
- Tekanan : 1 atm
- Viskositas Campuran : 1 cP : 0,0007 lb/ft.s
- Temperatur *in* : 38 ^{o}C : 100,4 ^{o}F
- Tempeatur *out* : 28 ^{o}C : 82,4 ^{o}F

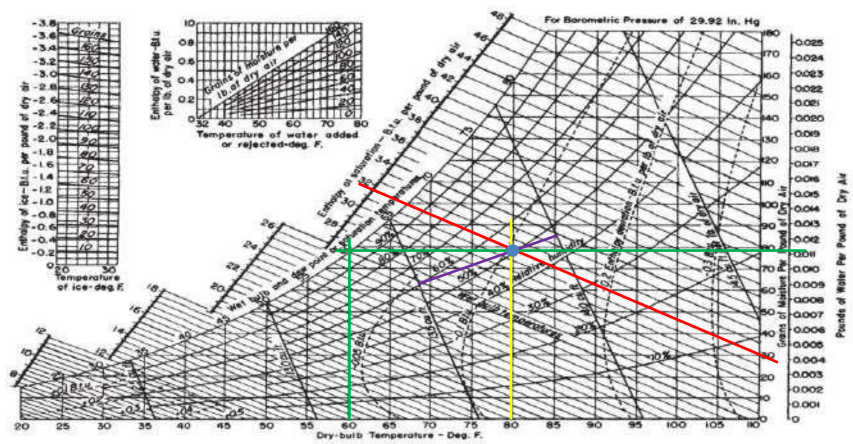


FIG. 12-2 Psychrometric chart—medium temperatures. Barometric pressure, 29.92 in.Hg. To convert British thermal units per pound dry air-degree Fahrenheit to joules per kilogram-kelvin, multiply by 4186.8; and to convert cubic feet per pound to cubic meters per kilogram, multiply by 0.0624.

Perry's chemical handbook

Dari gambar 12.2 diperoleh data berikut.

Rh = 51 % (garis biru)

Moisture content/Humidity = 0,011 lb *water*/lb *dry air* (garis hijau horizontal)

Sv = 13,9 ft^3/lb *dry air* (garis ungu)

Entalpi *saturation* = 31,6 btu/lb *dry air* (garis merah)

Entalpi *deviation* = -0,1 btu/lb *dry air* (garis putus-putus)

Entalpi sebenarnya = 31,5 btu/lb *dry air*

Dew point = 60,3 ^{o}F (garis hijau vertikal)

1. Laju alir volumetrik

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

$$W_c = \frac{40.556,3000 \text{ kg/jam}}{1000 \text{ kg/m}^3} = 40,5563 \frac{m^3}{jam} = 178,5640 \frac{gal}{menit}$$

2. Luas tower

Kandungan air, C_a = 3 gal/menit.ft^2 (gambar 12.14 *perry's chemical handbook*)

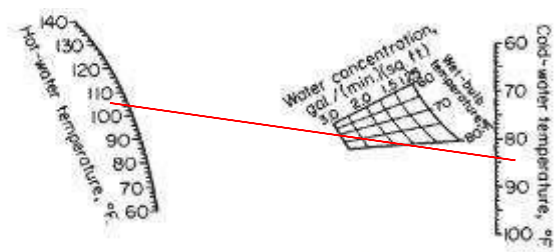


FIG. 12-14 Sizing chart for a counterflow induced-draft cooling tower, for induced-draft towers with (1) an upspray distributing system with 24 ft of fill or (2) a flume-type distributing system and 32 ft of fill. The chart will give approximations for towers of any height. (*Ecodyne Corp.*)

$$A = \frac{W_c}{C_a}$$

$$A = \frac{178,5640 \frac{gal}{menit}}{3 \frac{gal}{menit.ft^2}} = 59,5213 \text{ ft}^2$$

Faktor keamanan = 10%

$$A = \frac{59,5213 \text{ ft}^2}{0,9} = 66,1348 \text{ ft}^2$$

3. Daya yang dibutuhkan *fan*

Performa standar menara = 97% dengan daya yang dibutuhkan sebesar 0,037 HP/ft^2 (gambar 12.15 *perry's chemical handbook*)

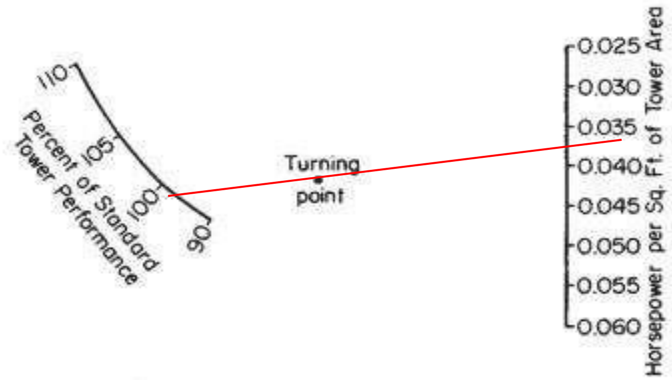


FIG. 12-15 Horsepower chart for a counterflow induced-draft cooling tower. [*Fluor Corp. (now Ecodyne Corp.)*]

Sehingga daya yang dibutuhkan untuk *fan* adalah :

=A × performa standar

= 66,1348 ft^2 × 0,037 HP/ft^2= 2,4470 HP

Kemudian daya motor diperoleh :

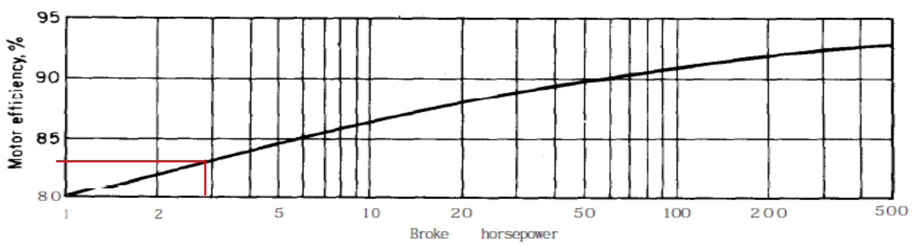


FIGURE 1438
Efficiencies of three-phase motors.

Efisiensi motor = 83%

$$MHP = \frac{\text{Daya fan}}{83\%}$$

$$MHP = \frac{2{,}4470\ HP}{83\%} = 2{,}9482\ HP \approx 3\ HP$$

4. Dimensi tower

Untuk memperoleh *duty coefficient*

$$\frac{W_L}{D_t} = 90{,}85 \times \frac{\Delta_h}{\Delta_T} \times \sqrt{\Delta_t + (0{,}3124\ \Delta_h}$$ pers 12.16 perrys

$$\frac{89.410{,}4190\ \text{lb/jam}}{D_t} = 90{,}85 \times \frac{83\ \text{btu/lb}}{18\ °\text{F}} \times \sqrt{82{,}4\ °\text{F} + (0{,}3124 \times 83\ \text{btu/lb}}$$

$$D_t = 20{,}5062\ \text{ft}$$

Direncangakan $Z_t = 1{,}5\ D_t$

$$D_t = \frac{A \times \sqrt{Z_t}}{C_t \times \sqrt{C_t}}$$ pers 12.15 perrys

$$(1{,}5D_t)^{0{,}5} = \frac{D_t \times (C_t \sqrt{C_t})}{A}$$

$$(1{,}5D_t)^{0{,}5} = \frac{20{,}5062\ \text{ft} \times (5\sqrt{5})}{66{,}1348\ \text{ft}^2} = 3{,}4666\ \text{ft}$$

$$D_t = \frac{(3{,}4666\ \text{ft})^2}{1{,}5} = 8{,}0118\ \text{ft} = 2{,}4426\ \text{m}$$

Tinggi tower $= 1{,}5 \times D_t = 3{,}4666$ m

16) *Daerator* (DA-3141)

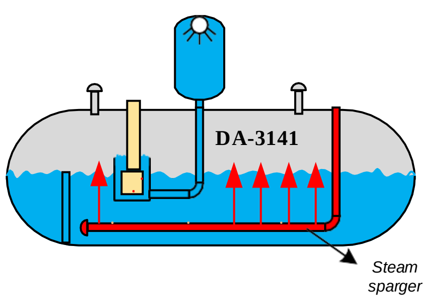
Fungsi : Menghilangkan gas terlarut dalam air umpan boiler

Tipe : SM7 D

Bahan konstruksi : *Carbon steel 70 C-Si (SA-515 Grade 70)*

Jumlah : 1 unit

Fasa : Cair



Gambar LC-52. *Daerator*

Data:

- Laju alir umpan : 3.030,6069 kg/jam : 6.681,2759 lb/jam
- Densitas campuran : 1.000 kg/m^3
- Tekanan : 1 atm
- Viskositas Campuran : 1 cP : 0,0007 lb/ft.s
- Waktu Penyimpanan : 60 menit : 1 jam

Direncanakan akan didesain *duo-tank daerator* yang mampu mengolah 6.681,2759 lb/jam air umpan *boiler.* Berdasarkan data tersebut maka diperoleh spesifikasi *daerator* sebagai berikut.

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

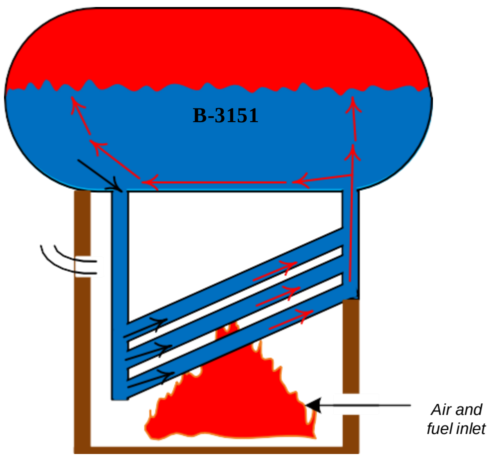
17) *Boiler* (B-3151)

Fungsi : Memproduksi *steam*

Tipe : TP-SZL25-2.45-All Water Tube Boiler

Jumlah : 1 unit

Fasa : Cair



Gambar LC-53. *Boiler*

Data:

- Laju alir umpan : 3.030,6069 kg/jam : 6.681,2759 lb/jam
- Efisiensi termal : 82%
- Regenerasi kondensat : 2.727,5462 kg/jam
- Air *make-up* : 303,0607 kg/jam

Berdasarkan data temperatur *steam* yang terbentuk diperoleh spesifikasi boiler sebagai berikut

		Item	★ TP-SZL4-1.25-AII TP-SZL4-1.6-AII TP-SZL4-2.45-AII	★ TP-SZL6-1.25-AII(快) TP-SZL6-1.6-AII TP-SZL6-2.45-AII	★ TP-SZL6-1.25-AII(組) TP-SZL6-1.57-AII TP-SZL6-2.45-AII	★ TP-SZL8-1.25-AII TP-SZL8-1.6-AII TP-SZL8-2.45-AII	★ TP-SZL10-1.25-AII TP-SZL10-1.6-AII TP-SZL10-2.45-AII	★ TP-SZL15-1.25-AII TP-SZL15-1.6-AII TP-SZL15-2.45-AII	★ TP-SZL20-1.6-AII TP-SZL20-2.45-AII	★ TP-SZL25-1.6-AII TP-SZL25-2.45-AII
			Specification of Package and Shop-assembled Water Tube Coal-fired Boiler							
Furnace		Rated Evaporation Capacity (t/h)	4	6	6	8	10.0	15	20	25
		Rated Pressure (Mpa)	1.25/1.6/2.45	1.25/1.6/2.45	1.25/1.57/ 2.45	1.25/1.6/2.45	1.25/1.6/2.45	1.25/1.6/2.45	1.6/2.45	1.6/2.45
		Rated Steam Temperature (℃)	194/204/225	194/204/225	194/204/225	194/204/225	194/204/225	194/204/225	204/225	204/250
		Water Supply Temperature (℃)	20	20	20	20	20	20	20	20
	Heating Surface	Body (m^2)	21(Radiation) 78.5(Convection)	21(Radiation) 105.1(Convection)	139.2	26.1(Radiation) 184(Convection)	29.5(Radiation) 204.1(Convection)	34.8(Radiation) 283.7(Convection)	504(Steam)	90.5(Radiation) 482.5(Convection) 118 (Superheater)
		Economizer (m^2)	38.5	109	130.8	130.8	174.4	348.8 (Steam)	377.6 (Steam) 236 (Water)	381.5
		Air preheater	/	/	/	/	/	/	/	/
		Grate Effective Surface (m^2)	5.3	7.8	7.8	10.2	12	18	21.2	28.6
	Suitable Fuel	Designed Coal Type	AII	AII	AII	AII	AII	AII	AII	AII
		Low heating Value(KCAL/kg)	5019	5019	5019	5019	5019	5019	5019	5019
		Fuel Consumption (kg/h)	591	884	880	1155	1441	2157	2866	3617
		Thermal Efficiency (%)	81	81	81	81.3	82	82	82	82
		Maximum shipping weight (t)	32	40	21	25	28	30	30	36.8
		Maximum shipping dimensions (m)	7.46 x 2.65 x 3.52	8.5 x 3.2 x 3.54	7 x 2.7 x 3.5	6.9 x 3.16 x 3.524	7.89 x 3.26 x 3.53	10 x 3.2 x 3.5	11 x 3.2 x 3.5	11.5 x 3.24 x 3.53
		Boiler Assembled Dimensions (Length x Width x Height) (m)	7.46 x 3.5 x 4.4	9.1 x 5.1 x 4.8	8 x 3.6 x 6.2	8.4 x 4.0 x 6.2	9.380 x 4.4 x 6.2	13 x 5.6 x 6.7	14 x 5.6 x 6.7	17 x 6.5 x 8.5
Auxiliary Machine	I.D Fan	Air volume (m^3/h)	17245	12000-24000	12000-24000	27045-31554	30000	33318-50356	36762-69347	60611-94052
		Air Pressure (Pa)	3099-3040	3980-4245	3980-4245	3895-3932	4030-4120	3628-3393	2824-3874	3112-3688
		Rotational Speed (r/min)	1750	1750	1750	1750	1750	1750	1750	1750
		★ Motor Efficiency (kw)	22	37	37	55	55	75	110	110
	F.D Fan	Air volume (m^3/h)	3742-7226	12000-7000	12000-7000	14840-16281	15012.2	31400-19400	23003-32079	33173-60960
		Air Pressure (Pa)	1275-2036	1442-2109	1442-2109	3151-2843	2241.6	1450-2380	2559-2668	2150-3401
		Rotational Speed (r/min)	3500	3500	3500	3500	3500	3500	3500	3500
		★ Motor Efficiency (kw)	5.5	7.5	11	15	15	22	30	55
	Feed Water Pump	Rotational Speed (r/min)	2900/3500	2900/3500	2900/3500	2900/3500	2900/3100	2900/3500	2900/3500	2900/3500
		Lift (m)	150	150	150	175	175	170	180	238
		★ Motor Efficiency (kw)	7.5	7.5	7.5	15	15	22	30	45
	Speed Governor	Model	GL-5P	GL-10W	GL-10P/II0	GL-16P	GL-16P	GL-20P/II	GL-20PWI	GL-30P
		Motor Model	YCT112-4A	YCT112-4B	YCT112-4B	YCT132-4A	YCT132-4A	YCT132-4B	JZTY22-4	YCT160-4A
		Motor Power	1.1	1.1	1.1	1.1	1.1	1.5	1.5	2.2
		Motor Rotational Speed	125-1250	125-1250	125-1250	125-1250	125-1250	125-1250	125-1250	125-1250
	Cinder Conveyor	Motor Power	1.1	1.5	1.5	1.5	1.5	2.2	2.2	2.2
		Motor Rotational Speed	960	960	960	960	960	960	950	960
		Dust Collector Model	XTD-4	XTD-6	XTD-6	XTD-10	XTD-10	XTD-15	XTD-20	XTD-25

Boiler product catalog, halaman 5

18) Kebutuhan Air

Jenis air yang digunakan dalam pabrik ini terdiri menjadi 4 bagian.

a. Air Sanitasi

- Perumahan

  Kebutuhan air per orang = 250 l/hari = 0,24 m^3/hari

  Jumlah rumah = 30 unit

  Jumlah orang dalam 1 rumah = 3 orang

  Total kebutuhan air = 22,50 m^3/hari = 0,9375 m^3/jam

  = 9375,5000 kg/jam

- Perkantoran

  Kebutuhan air per orang = 100 l/hari = 0,10 m^3/hari

  Jumlah karyawan = 123 orang

  Total kebutuhan air = 12,30 m^3/hari = 0,5125 m^3/jam

  = 512,5000 kg/jam

- Laboratorium = 15 kg/jam
- Poliklinik = 15 kg/jam
- Pemadam Kebakaran = 70 kg/jam
- Masjid dan Kantin = 61,67 kg/jam

  Total kebutuhan air sanitasi = 1,611,6660 kg/jam

b. Air Proses

Air proses digunakan pada alat *mixing tank* 1 sebesar = 770,3801 kg/jam

c. Air Pendingin

Adapun alat yang menggunakan air pendingin antara lain sebagai berikut.

Tabel LC.3 Kebutuhan Air Pendingin

Kebutuhan Air Pendingin	**Kg/jam**
Condensor	1.801,0493
Barometric Condensor	15.078,8760
Cooler 1	15.310,3459
Netralizer Reactor	113,6108
Cooler 2	7.383,2737
Total	**39.687,1558**

Pada saat operasi kontinu, *cooling tower* mengalami kehilangan air, adapaun air yang hilang adalah sebagai berikut.

Evaporaion loss

Evaporation loss dapat dihitung dengan persamaan 12-10 *Perry's Chemical Engineering Handbook Ed 7th* Halaman 12-17.

$W_e = 0{,}00085\ W_c\ (T_2 - T_1)$

Keterangan :

W_c = Air pendingin yang disirkulasi (gal/min)

T_1 = Temperatur air pendingin masuk (°F)

T_2 = Temperatur air pendingin keluar (°F)

W_c = 39.687,1558 kg/jam

W_c = 39,69 m^3/jam

W_c = 174,74 gal/min

W_e = 0,00085 x 174,74 gal/min (100,40 °F – 82,4 °F)

W_e = 2,67 gal/min

W_e = 607,21 kg/jam

Drift loss

Berdasarkan *Perry's Chemical Engineering Handbook Ed 7th* Halaman 12-17, air yang hilang karena *drift loss* biasanya diantara 0,1% - 0,2% dari suplai air. Maka ditetapkanlah air pendingin yang hilang karena *drift loss* sebesar 0,15% dari air suplai yang disirkulasi.

W_d = 0,15% x 39.687,1558 kg/jam

W_d = 59,53 kg/jam

Blowdown

Air yang hilang karena *blowdown* bergantung pada jumlah siklus sirkulasi air pendingin, biasanya antara 3-5 siklus (*Perry's Chemical Engineering Handbook Ed 7th* Halaman 12-17). Ditetapkan 4 siklus, berdasarkan persamaan 12-12 *Perry's Chemical Engineering Handbook Ed 7th* Halaman 12-17, maka :

$W_b = W_c$ / (Siklus – 1)

W_b = 39.687,1558 kg/jam / (4 – 1)

W_b = 202,40 kg/jam

Total air *make up* yang dibutuhkan untuk sirkulasi air pendingin adalah :

$W_m = W_e + W_d + W_b$

W_m = 869,15 kg/jam

Sehingga kebutuhan air pendingin total adalah = 40.556,30 kg/jam

d. Air umpan *boiler* (*steam*)

Air umpan *boiler* adalah air yang digunakan untuk menghasilkan *steam*. Kebutuhan *steam* dapat dilihat pada Tabel LC-4.

Tabel LC.4 Kebutuhan *Steam*

Nama Alat	Kebutuhan (kg/jam)
Storage Tank PFAD	46,0039
Preheater deodorizer	110,2922
Reboiler	334,5085
Steam jet ejector	1.666,2198
Heater KOH	102,1552
Total	**2.259,1797**

Jika efisiensi termal dari *boiler* yang digunakan adalah 82%, maka kebutuhan air umpan *boiler* yang digunakan untuk produksi *steam* adalah 2.755,0971 kg/jam.

Kemudian untuk keamanan selama sirkulasi dalam produksi *steam* dan kehilangan air diambil faktor keamanan sebesar 10% dari total kebutuhan *steam*. Maka kebutuhan air umpan *boiler* total adalah 3.030,6069 kg/jam.

19) Kebutuhan Listrik

Adapun kebutuhan listrik pada pabrik ini adalah sebagai berikut.

- Alat Utama

  Kebutuhan listrik alat utama dapat dilihat pada tabel LC.5 dan LC.6.

Tabel LC.5 Kebutuhan Listrik Alat Utama (Tangki)

No	Nama Alat	Kode Alat	Daya (HP)
1	*Mixing Tank 1*	MT-1111	0,5
2	*Storage PFAD*	ST-1011	2,0
3	*Netralizer Reactor*	R-2121	0,5
4	*Mixing Tank 2*	MT-4212	0,5
5	*Mixing Tank 3*	MT-4223	0,5
Total			**4**

Tabel LC.6 Kebutuhan Listrik Alat Utama (Pompa dan Conveyor)

No	Nama Alat	Kode Alat	Daya (HP)
1	*Continous Flow Conveyor* 1	CFC-1101	0,5
2	*Continous Flow Conveyor* 2	CFC-4182	0,5
3	Pompa Sentrifugal	P-1011	0,5

4	Pompa Sentrifugal	P-1031	0,5
5	Pompa Sentrifugal	P-1071	0,5
6	Pompa Sentrifugal	P-1122	0,5
7	Pompa Sentrifugal	P-2131	0,5
8	Pompa Sentrifugal	P-3151	0,5
9	Pompa Sentrifugal	P-4207	0,5
10	Pompa Sentrifugal	P-4218	0,5
11	Pompa Sentrifugal	P-4222	0,5
12	Pompa Sentrifugal	P-4233	0,5
Total			**6**

Total kebutuhan listrik alat utama = 10 HP = 7,46 kWh

- Alat Utilitas

  Kebutuhan listrik alat utilitas dapat dilihat pada tabel LC.7 dan LC.8.

Tabel LC.7 Kebutuhan Listrik Alat Utilitas (Tangki)

No	Nama Alat	Kode Alat	Daya (Hp)
1	*Mixing PAC*	ST-2032	0,5
2	*Mixing Kaporit*	ST-2043	0,5
3	*Mixing Kapur Tohor*	ST-2054	0,5
4	*Coagulation Tank*	CT-2061	0,5
5	*Floculation Tank*	FLT-2071	0,5
6	*Cooling Tower*	CT-3161	3
Total			**5,5**

Tabel LC.8 Kebutuhan Listrik Alat Utilitas (Pompa)

No	Nama Alat	Kode Alat	Daya (Hp)
1	Pompa Sentrifugal	P-1011	4
2	Pompa Sentrifugal	P-1021	0,5
3	Pompa Sentrifugal	P-2032	0,5
4	Pompa Sentrifugal	P-2043	0,5
5	Pompa Sentrifugal	P-2054	0,5
6	Pompa Sentrifugal	P-2071	1
7	Pompa Sentrifugal	P-2081	1
8	Pompa Sentrifugal	P-3091	2

9	Pompa Sentrifugal	P-3101	1
10	Pompa Sentrifugal	P-3115	1
11	Pompa Sentrifugal	P-3121	1
12	Pompa Sentrifugal	P-3136	0,5
13	Pompa Sentrifugal	P-3141	0,5
Total			**14**

Total kebutuhan listrik alat utilitas = 19,5 HP = 14,55 kWh

- Kebutuhan listrik untuk peralatan instrumentasi seperti alat control diperkirakan = 50 kWh

- Kebutuhan listrik untuk peralatan bengkel seperti alat pemotong, mesin las dan lainnya diperkirakan = 100 kWh

- Kebutuhan listrik untuk penerangan diperkirakan = 272 kWh

- Kebutuhan listrik untuk peralatan kantor seperti mesin *photocopy*, computer, dispenser, AC, kulkas dan lainnya diperkirakan = 32,25 kWh

  Sehingga total kebutuhan listrik sebesar = 476,26 kWh

LAMPIRAN D. PERHITUNGAN ANALISA EKONOMI

1. Investasi

Capital Investment adalah modal yang dibutuhkan untuk mendirikan suatu pabrik dan menjalankan pada saat produksi sampai diyakini pabrik berjalan dengan normal. *Capital Investment* terdiri dari biaya untuk mendirikan pabrik (*Fixed Capital Investment*) dan biaya untuk menjalankan pabrik dalam waktu tertentu (*Working Capital Investment*).

1.1 Menghitung Biaya Investasi

Untuk memperkirakan biaya investasi dalam desain awal suatu pabrik dapat digunakan beberapa cara, yaitu:

a. Perkiraan taksiran (*ratio estimate*) berdasarkan data beberapa harga yang sama dengan ketelitian perhitungan lebih dari 30%.
b. Perkiraan lapangan (*factored estimate*) berdasarkan pada pengetahuan peralatan utama dengan ketelitian sampai dengan 30%.
c. Perkiraan rancangan awal (*preliminary estimate*) brdasarkan data yang cukup akurat untuk menghitung pendapatan dengan ketelitian sampai 20%.
d. Perkiraan pengaturan proyek (*project control estimate*) berdasarkan data yang lebih lengkap sebelum kelengkapan penggambaran dan spesifikasi dengan ketelitian sampai 10%.
e. Perkiraan kontraktor (*contractor's estimate*) berdasarkan keteknikan lengkap tenatang penggambaran, spesifikasi dan survey daerah dengan ketelitian perkiraan sampai 5%.

Cara perhitungan untuk memperkirakan biaya investasi yang digunakan adalah dengan menggunakan metode *percentage of delivered equipment cost*. Metode ini merupakan penentuan *Total Capital Investment* berdasarkan harga peralatan sampai tempat setelah penambahan biaya pajak bea cukai, asuransi dan pengangkutan. (Peter, Hal: 180). Taksiran investasi dengan metode ini juga dipengaruhi oleh tipe proses terlibat, kelengkapan konstruksi yang diperlukan, lokasi pabrik, dan variabel lainnya.

1.2 Menghitung Harga Alat

Dalam menghitung harga alat dapat dilakukan dengan dua cara, yaitu:

a. Cost Index

Untuk menghitung harga peralatan di tahun 2029 ditentukan dengan persamaan:

$$\text{Harga Sekarang} = \text{harga awal} \times \left[\frac{\text{index harga sekarang}}{\text{index harga awal}} \right]$$

b. Capacity factor

Untuk menentukan harga peralatan dengan kapasitas tertentu pada tahun yang berbeda digunakan persamaan:

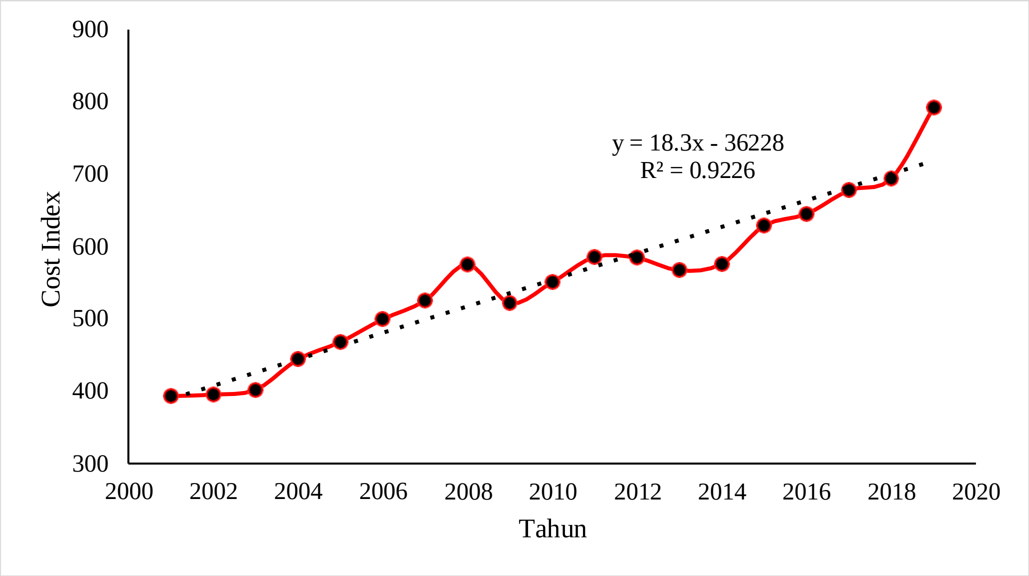
$$\text{Harga Alat A} = \text{harga alat B} \times \left[\frac{\text{index harga sekarang}}{\text{index harga awal}} \right]$$

Berikut ini adalah tabel cost index, dapat dilihat pada Tabel D.1.

Tabel D.1 Daftar Cost Index

Tahun	**Cost Index**
2001	393,4
2002	395,6
2003	402
2004	444,2
2005	468,2
2006	499,6
2007	525,5
2009	575,4
2010	521,9
2011	550,8
2012	585,7
2013	584,6
2014	567,3
2015	576,1
2016	628,9
2017	645,2
2018	677,8
2019	694,2

Sumber: Chemical Engineering Plant Cost Index (http://www.chemengonline.com/pci-home)



Gambar D.1 Grafik Hubungan Harga Index terhadap Tahun

Persamaan yang diperoleh sesuai Gambar D.1 adalah:

$$y = 18,3\ x - 36.228$$

Dengan menggunakan persamaan diatas dapat dicari harga index pada tahun perancangan pabrik, dalam hal ini pada tahun 2029, yaitu:

$$y = 18,3\ (2029) - 36.228$$

$$y = 902,7$$

Harga pembelian peralatan dihitung dengan index harga 2014 yang diambil dari matche.com/equipcost, dimana index tahun 2029 adalah 902,7. Harga peralatan dihitung berdasarkan US$.

1.2.1 Perhitungan Alat Proses

Perhitungan *Storage Tank* KOH

a. Kapasitas Tangki = 2622 gallon
b. Index ditahun 2014 = 567,3
c. Index ditahun 2029 = 902,7
d. Harga ditahun 2014 = US$ 29.300,00

Harga satu unit tangki ditahun 2029 adalah:

$$\text{Harga tangki} = \text{Harga 2014} \times \left[\frac{\text{index harga 2029}}{\text{Index harga 2014}}\right]$$

$$\text{Harga tangki} = US\$29.300,00 \times \left[\frac{902,7}{576,1}\right]$$

Harga tangki = US$ 45.910,62 = Rp 669.856.651,62

Dengan cara yang sama diperoleh harga masing-masing peralatn lain pada tabel di bawah ini:

Tabel D.2 Perhitungan Peralatan Proses

Alat	Jumlah	Harga Per Unit Pada 2014 (US $)	Harga (US $)	
			2014	2029
Storage Tank KOH	1	29.300,00	29.300,00	45.910,62
Continous Flow Conveyor KOH	2	34.300,00	68.600,00	107.490,40
Mixing Tank 1	1	261.400,00	261.400,00	409.591,70
Heater KOH	1	2.800,00	2.800,00	4.387,36
Storage Tank PFAD	1	881.300,00	881.300,00	1.380.922,60
Preheater Deodorizer	1	2.400,00	2.400,00	3.760,60
Deodorizer	1	133.500,00	133.500,00	209.183,21
Steam jet ejector	1	2.400,00	2.400,00	3.760,60
Barometric Condensor	1	7.600,00	7.600,00	11.908,56
Condensor	1	30.200,00	30.200,00	47.320,85
Reboiler	1	21.000,00	21.000,00	32.905,22
Accumulator	1	2.000,00	2.000,00	3.133,83
Cooler 1	1	2.300,00	2.300,00	3.603,91
Netralizer Reactor	1	78.600,00	78.600,00	123.159,56
Cooler 2	1	1.900,00	1.900,00	2.977,14
Decanter	2	54.000,00	108.000,00	169.226,87
Storage Tank Triclocarban	1	4.900,00	4.900,00	7.677,89
Storage Tank Sunset Yellow	1	4.900,00	4.900,00	7.677,89
Storage Tank EDTA	1	4.900,00	4.900,00	7.677,89
Continous Flow Conveyor Additive	2	34.300,00	68.600,00	107.490,40
Storage Cocoamidopropyl	1	3.600,00	3.600,00	5.640,90
Storage Gliserol	1	3.600,00	3.600,00	5.640,90
Mixing Tank 2	1	122.500,00	122.500,00	191.947,14
Storage Tank Kayu Manis	1	3.600,00	3.600,00	5.640,90
Mixing Tank 3	1	89.900,00	89.900,00	140.865,70
Pompa PFAD Dari Storage Tank Ke Deodorizer	2	5.600,00	11.200,00	17.549,45
Pompa Bottom Product Deodorizer Ke Netralizer Reactor	1	7.300,00	7.300,00	11.438,48

Pompa Reflux Ke Deodorizer Dan Destilat Ke Limbah Pembuangan	1	3.700,00	3.700,00	5.797,59
Pompa Larutan KOH 25% Ke Netralizer Reactor	1	5.600,00	5.600,00	8.774,73
Pompa Sabun Cair Ke Decanter	1	7.300,00	7.300,00	11.438,48
Pompa Sabun Cair Ke Mixing Tank 2	1	7.300,00	7.300,00	11.438,48
Pompa Gliserol Dan Cocoamidopropyl Ke Tangki Mixing Tank 2	1	4.700,00	4.700,00	7.364,50
Pompa Minyak Kayu Manis Ke Mixing Tank 3	1	2.500,00	2.500,00	3.917,29
Pompa Sabun Cair Ke Mixing Tank 3	1	7.300,00	7.300,00	11.438,48
Pompa Sabun Cair Ke Storage Tank Sabun Cair	1	7.300,00	7.300,00	11.438,48
Total			**2.004.000,00**	**3.140.098,59**

Total harga peralatan utama:

a. Biaya peralatan utama pabrik (A) = US$ 3.140.098,59

b. Biaya pengangkutan dan asuransi (12,5%A) = US$ 376.811,83

c. Pajak bea cukai (10%A) = US$ 314.009,86

Total = US$ 3.830.920,28

= Rp 55.894.850.867,50

1.2.2 Harga Alat Utilitas

Berikut ini daftar harga peralatan utilitas apat dilihat pda Tabel D.3.

Tabel D.3 Harga Peralatan Utilitas

Alat	Jumlah	Harga Per Unit Pada 2014 (US $)	Harga (US $)	
			2014	2029
Bar Screen	1	35.000	35.000,00	54.842,04
Bak Penampung Air Sungai	2	122.100	244.200,00	382.640,76
Tangki Pelarutan PAC	1	1.600	1.600,00	2.507,06
Tangki Pelarutan Kapur Tohor	1	1.600	1.600,00	2.507,06
Tangki Pelarutan Kaporit	1	1.600	1.600,00	2.507,06
Coagulation Tank	1	93.100	93.100,00	145.879,83
Floculation Tank	1	93.100	93.100,00	145.879,83
Sedimentation Tank	1	6.100	6.100,00	9.558,18
Sand Filter	2	14.500	29.000,00	45.440,55
Carbon Filter	2	14.500	29.000,00	45.440,55
Bak Air Bersih	2	122.100	244.200,00	382.640,76
Mix-Bed Ion Exchange	2	14.500	29.000,00	45.440,55
Demin Water Tank	1	6.400	6.400,00	10.028,26
Cooling Tower	1	97.600	97.600,00	152.930,95
Daerator	1	47.100	47.100,00	73.801,72
Boiler	1	1.942.600	1.942.600,00	3.043.889,98
Pompa Air Sungai Ke Bak Penampungan Air	2	19.200	38.400,00	60.169,55
Pompa Air Sungai Dari Bak Penampungan Air Ke Tangki Koagulasi	1	19.200	19.200,00	30.084,78
Pompa Larutan PAC, Kaporit, Kapur Tohor Ke Tangki Koagulasi	1	2.500	2.500,00	3.917,29
Pompa Air Dari Tangki Koagulasi Ke Tangki Flokulasi	1	19.200	19.200,00	30.084,78
Pompa Air Dari Tangki Flokulasi Ke Tangki Sedimentasi	1	19.200	19.200,00	30.084,78
Pompa Air Dari Tangki Sedimentasi Ke Sand Filter	1	19.200	19.200,00	30.084,78
Pompa Air Dari Sand Filter Ke Carbon Filter	1	19.200	19.200,00	30.084,78
Pompa Air Dari Carbon Filter Ke Tangki Penyimpanan Air	1	19.200	19.200,00	30.084,78
Pompa Air Dari Tangki Penyimpanan Ke Mix-Bed Ion Exchange	1	19.200	19.200,00	30.084,78

Pompa Air Dari Mix-Bed ion exchange Ke Tangki Air Demin	1	19.200	19.200,00	30.084,78
Pompa Air Demin Ke Daerator	1	7.300	7.300,00	11.438,48
Pompa Air Dari Daerator Ke Boiler	2	7.300	14.600,00	22.876,97
Total			**3.117.600,00**	**4.885.015,66**

Total harga peralatan utilitas:

a. Biaya peralatan utilitas (B)	= US$	4.885.015,66
b. Biaya pengangkutan dan asuransi (12,5%B)	= US$	586.201,88
c. Pajak bea cukai (10%B)	= US$	488.501,57
Total	= US$	5.959.719,10
	= Rp	86.954.983.565,14

1.2.3 Harga Alat Kantor

Berikut ini daftar harga alat kantor disajikan dalam Tabel D.4. dibawah ini:

Tabel D.4 Harga Peralatan Kantor

Nama Alat	**Jumlah**	**Harga Per Unit Pada 2014 (US $)**	**Harga (US $)**	
			2014	**2029**
Komputer	30	250	7.500	11.752
Meja	45	30	1.350	2.115
AC	50	150	7.500	11.752
Dispenser	15	25	375	588
Kulkas	5	190	950	1.489
Mesin Photo Copy	3	500	1.500	2.350
Lemari	20	45	900	1.410
Kursi	300	8	2.400	3.761
Papan Tulis	10	10	100	157
Total			**22.575**	**35.373**

Total Biaya Peralatan = Biaya peralatan utama + Biaya peralatan utilitas + biaya peralatan kantor

Total Biaya Peralatan = US$ 3.830.920,28 + US$ 5.959.719,10 + US$ 35.373,00

Total Biaya Peralatan = US$ 9.826.012,50 = Rp 143.365.944.122,41

1.2.4 Harga Pembelian Bahan Baku

Berikut ini adalah harga pembelian bahan baku dapat dilihat pada Tabel D.5.

Tabel D.5 Harga Pembelian Bahan Baku

Nama Bahan	**Kebutuhan (Kg/Jam)**	**Kebutuhan (Kg/Tahun)**	**Harga Per Kg 2019 (US $)**	**Harga (US $)**	
				2019	**2029**
Palm Fatty Acid Distillate	1341,53	442.705,63	0,60	265.623,38	302.712,06
Kalium Hidroksida	263,83	87.063,51	0,89	77.486,52	88.305,87
Triclocarban	21,97	7.250,83	15,00	108.762,42	123.948,79
Sunset Yellow FCF	21,97	7.250,83	50,00	362.541,41	413.162,64
Etilen Diamin Tetra Asetat	4,39	1.450,17	2,00	2.900,33	3.305,30
Cocoamidopropyl	54,93	18.127,07	1,20	21.752,48	24.789,76
Gliserol	219,72	72.508,28	0,90	65.257,45	74.369,28
Minyak Kayu Manis	5,04	1.663,34	30,00	49.900,20	56.867,71

Poly Aluminium Chloride	1,72	568,86	0,40	227,55	259,32
Kapur Tohor	0,17	56,89	2,00	113,77	129,66
Kaporit	0,23	75,85	1,30	98,60	112,37
Total				**954.664**	**1.087.962**

1.2.5 Menghitung Gaji Karyawan

Sistem gaji karyawan di pabrik sabun cair beraroma kayu manis dari PFAD ini berdasarkan gaji upah minimum relatif (UMR) wilayah Provinsi Sumatera Barat tahun 2029 dengan nilai UMR sebesar Rp. 4.927.405. Daftar gaji karyawan pra rancangan pabrik sabun cair beraroma kayu manis dari PFAD dapat dilihat pada Tabel D.6.

Tabel D.6 Daftar Gaji Karyawan

Jabatan	Jumlah	Sistem Gaji	Gaji/Bulan (Per Orang)	Total/Bulan	Total/Tahun
Dewan Komisaris	1	5 x UMR	$ 1.688,57	$ 1.688,57	$ 20.262,86
Direktur	1	3,5 x UMR	$ 1.182,00	$ 1.182,00	$ 14.184,00
Kepala Bagian	7	2,5 x UMR	$ 844,29	$ 5.910,00	$ 70.920,02
Karyawan Akuntasi dan Anggaran	1	1,5 x UMR	$ 506,57	$ 506,57	$ 6.078,86
Karyawan Pemasaran	1	1,5 x UMR	$ 506,57	$ 506,57	$ 6.078,86
Karyawan Administrasi dan SDM	2	1,5 x UMR	$ 506,57	$ 1.013,14	$ 12.157,72
Karyawan Logistik	1	1,5 x UMR	$ 506,57	$ 506,571	$ 6.078,86
Karyawan Litbang	3	1,5 x UMR	$ 506,57	$ 1.519,71	$ 18.236,5774
Sekretaris	1	1,5 x UMR	$ 506,57	$ 506,57	$ 6.078,86
Kepala satpam	1	1,2 x UMR	$ 405,26	$ 405,26	$ 4.863,09
Sopir	3	1 x UMR	$ 337,71	$ 1.013,14	$ 2.157,72
Dokter	2	2 x UMR	$ 675,43	$ 1.350,86	$ 16.210,29
Perawat	2	1 x UMR	$ 337,71	$ 675,43	$ 8.105,15
Karyawan Produksi	16	1,5 x UMR	$ 506,57	$ 8.105,15	$ 97.261,75
Karyawan Utilitas	20	1,5 x UMR	$ 506,57	$ 10.131,43	$ 121.577,1823
Karyawan Mesin	12	1,5 x UMR	$ 506,57	$ 6.078,86	$ 72.946,31
Karyawan Laboratorium	16	1,5 x UMR	$ 506,57	$ 8.105,14	$ 97.261,75

Karyawan Instrumentasi dan Elektrikal	8	1,5 x UMR	$ 506,57	$ 4.052,57	$ 48.630,87
Satpam	12	1,1 x UMR	$ 371,49	$ 4.457,83	$ 53.493,96
Supervisor	4	2 x UMR	$ 675,43	$ 2.701,72	$ 32.420,58
Office boy	9	1 x UMR	$ 337,71	$ 3.039,43	$ 36.473,15
Total	**123**		**$12.427,89**	**$ 63.456,53**	**$ 761.478,42**

Maka total gaji karyawan selama 1 tahun adalah US$ 761.478,42 atau setara dengan Rp 11.110.312.794,00.

1.2.6 Menghitung Harga Penjualan Produk

Produk berupa sabun cair beraroma kayu manis yang diproduksi sebanyak 2.525,25 kg/jam, maka dapat ditentukan total produksi pertahun adalah sebagai berikut:

$$\text{Produk} = 2.525{,}25\ \frac{\text{kg}}{\text{jam}} \times 24\ \frac{\text{jam}}{\text{hari}} \times 330\ \frac{\text{hari}}{\text{tahun}}$$

Produk = 20.000.000 kg/tahun

Jika diketahui densitas sabun cair 1,0398 kg/liter, jadi total produksi sabun cair adalah 19.234.963,9325 liter/tahun.

Harga penjualan perliter adalah US$ 3,4269/liter (Rp 50.000/liter), sehingga total penjualan sabun cair adalah US$ 65.916.280,62 atau setara dengan Rp 961.748.196.625,96.

2. Komponen Investasi

2.1 Menghitung Total Capital Investment

Komponen	Solid-Fluid Processing Plant	Biaya (US $)
Direct Cost		
Biaya peralatan	100%	$ 9.826.012,50
pemasangan alat	39%	$ 3.832.144,88
instrumentasi dan alat kontrol	13%	$ 1.277.381,63
pemasangan pipa	31%	$ 3.046.063,88
Pemasangan instalasi listrik	10%	$ 982.601,25
Bangunan	29%	$ 2.849.543,63
Pengembangan area	10%	$ 982.601,25
Fasilitas pelayanan	55%	$ 5.404.306,88
Lahan	6%	$ 589.560,75
Total Direct Cost		**$ 28.790.216,63**
Indirect Cost		
Engineering and supervision	32%	$ 3.144.324,00
Biaya konstruksi	34%	$ 3.340.844,25
Total Indirect Cost		**$ 6.485.168,25**
Total Direct Cost dan Indirect Cost		**$ 35.275.384,89**
Biaya kontraktor	18%	$ 6.349.569,28
Biaya tidak terduga	36%	$ 12.699.138,56
		$ 19.048.707,84
Fixed Capital Investment		**$ 54.324.092,72**

2.2 Menghitung Working Capital Investment (WCI)

Total Capital Investment, TCI

TCI = FCI + WCI

WCI = 15% TCI

Maka,

TCI = US$ 54.324.092,72 + 0,15 TCI

1 – 0,15 TCI = US$ 54.324.092,72

0,85 TCI = US$ 54.324.092,72

TCI = US$ 63.910.697,32 = Rp 932.485.833.735,50

WCI = 15% TCI

WCI = 0,15 x US$ 63.910.697,32

WCI = US$ 9.586.604,60 = Rp 139.872.875.060,33

3. Sumber Investasi

Sumber investasi atau permodalan dapat dikelompokkan menjadi:

a. Modal Sendiri
b. Pinjaman Bank

Modal atau investasi untuk perkiraan pabrik sabun cair dari PFAD ini diperoleh dari modal sendiri 50% dan pinjaman bank 50%:

- Modal Sendiri = 50% x US$ US$ 63.910.697,32
  = US$ 31.955.348,66 = Rp 466.242.916.867,75

- Modal Bank = 50% x US$ 63.910.697,32
  = US$ 31.955.348,66 = Rp 466.242.916.867,75

4. Biaya Produksi Total (*Total Production Cost*)

Total Production Cost menurut Peter terdiri dari:

1. Manufacturing Cost (MC) / Biaya Produksi
2. General Expanse / Biaya Umum

Perhitungan komponen biaya produksi total dapat dilihat pada Tabel D.7.

Tabel D.7 Perhitungan Komponen Biaya Produksi Total

Parameter	***Fixed Cost* (US$)**	***Variable Cost* (US$)**
1. Manufacturing Cost ***A.Direct Production Cost (DPC)***		
Raw Material		$ 1.087.962,72
Operating Labor		$ 761.478,42
Direct Supervisory		$ 114.221,76
Utilities		0,15 TPC
Maintenance and Repairs		$ 2.716.204,64
Operating Supplies		$ 380.268,65
Laboratory Charges		$ 114.221,76
Patent and Royalty		0,03 TPC
Total Direct Production Cost		**$ 5.174.357,99 + 0,18 TPC**
2. Fixed Charge (FC)		
Depresiasi	$ 5.432.409,27	
Local Tax	$ 1.086.481,85	
Insurance	$ 325.944,56	
Total Fixed Charge	**$ 6.844.835,68**	
Plant Overhead Cost		0,1 TPC
B. General Expenses		
Administrative Cost		0,04 TPC
Distribution Cost		0,10 TPC
Research and Development Cost		0,05 TPC
Financing		$ 5.112.855,79
Total General Expenses		**$ 5.112.855,79 + 0,19 TPC**

Total Production Cost = *Manufacturing Cost* + *General Expenses*

TPC = (5.174.357,99 + 0,18 TPC) + (6.844.835,68 + 0,10 TPC)

+ 5.112.855,79 + 0,19 TPC

TPC = 17.132.049,46 + 0,47 TPC

0,53 TPC = 17.132.196,77

TPC = US$ 32.324.621,62

= Rp 471.630.775.496,59

Sehingga :

- *Direct Production Cost* = US$ 10.992.789,88

  = Rp 160.392.630.484,97
- *Fixed Charge* = US$ 6.844.835,68

  = Rp 99.869.232.793,07
- *Plant Overhead Cost* = US$ 3.232.462,16

  = Rp 47.163.077.549,66
- *General Expenses* = US$ 11.254.533,89

  = Rp 164.208.714.043,19
- *Fixed Cost* = US$ 6.844.835,68

  = Rp 99.869.232.793,07
- *Variable Cost* = US$ 25.479.785,94

  = Rp 371.761.542.703,52

5. Analisa Kelayakan Investasi

5.1 Laba

- *Total Capital Investment* (TCI) = US$ 63.910.697.32
- Depresiasi (10% FCI) = US$ 5.432.409,27
- Total Penjualan Produk (TS) = US$ 65.916.280,62
- *Total Production Cost* (TPC) = US$ 32.324.621,62

Laba Sebelum Pajak (Laba Kotor)

= Total Penjualan – Biaya Produksi

= US$ 65.916.280,62 – US$ 32.324.621,62

= US$ 33.591.659,00 = Rp 490.117.421.129,37

Pajak 12,5% (Dirjen Pajak)

Laba Bersih = Laba Kotor – Pajak

= US$ 33.591.659,00 – US$ 4.198.957,38

= US$ 29.392.701,63

= Rp 428.852.743.488,20

5.2 Laju Pengembalian Modal (*Rate Of Return*)

$$\text{ROR} = \frac{\text{Laba Bersih}}{\text{TCI}} \times 100\%$$

$$\text{ROR} = \frac{\text{US\$ 29.701,63}}{\text{US\$ 63.910.697.32}} \times 100\%$$

ROR = 46%

5.3 Waktu Pengembalian Modal (*Pay Out Time*)

Masa *start up* 2 tahun

Umur pabrik 10 tahun

Kapasitas produk pabrik selama beroperasi :

Tahun I : 70%

Tahun II : 90%

Tahun III dan seterusnya : 100%

Keuntungan masing-masing kapasitas setelah ditambah depresiasi

1. Kapasitas 70%

   = total penjualan 70% - [{*fixed cost* + (*variable cost* x 70%)}
   + depresiasi]

   = US$ 26.893.119,87 = Rp 392.382.720.820,15

2. Kapasitas 90%

   = total penjualan 90% - [{*fixed cost* + (*variable cost* x 90%)}
   + depresiasi]

   = US$ 34.980.418,81 = Rp 510.380.051.604,64

3. Kapasitas 100%

   = total penjualan 100% - [{*fixed cost* + (*variable cost* x 100%)}
   + depresiasi]

   = US$ 39.024.068,28 = Rp 569.378.761.996,89

Jumlah keuntungan selama *start up* adalah = US$ 61.873.538,68

= Rp 902.762.772.424,80

$$\text{POT} = 2 + \frac{\text{TCI} - \text{Keuntungan Selama } \textit{Start Up}}{\text{Keuntungan Kapasitas 100\%}}$$

$$\text{POT} = 2 + \frac{\text{US\$ 63.910.697.32 - US\$ 61.873.538,68}}{\text{US\$ 39.024.068,28}}$$

$$\text{POT} = 2{,}05$$

Maka diperoleh POT sebesar 2 tahun 6 bulan 15 hari

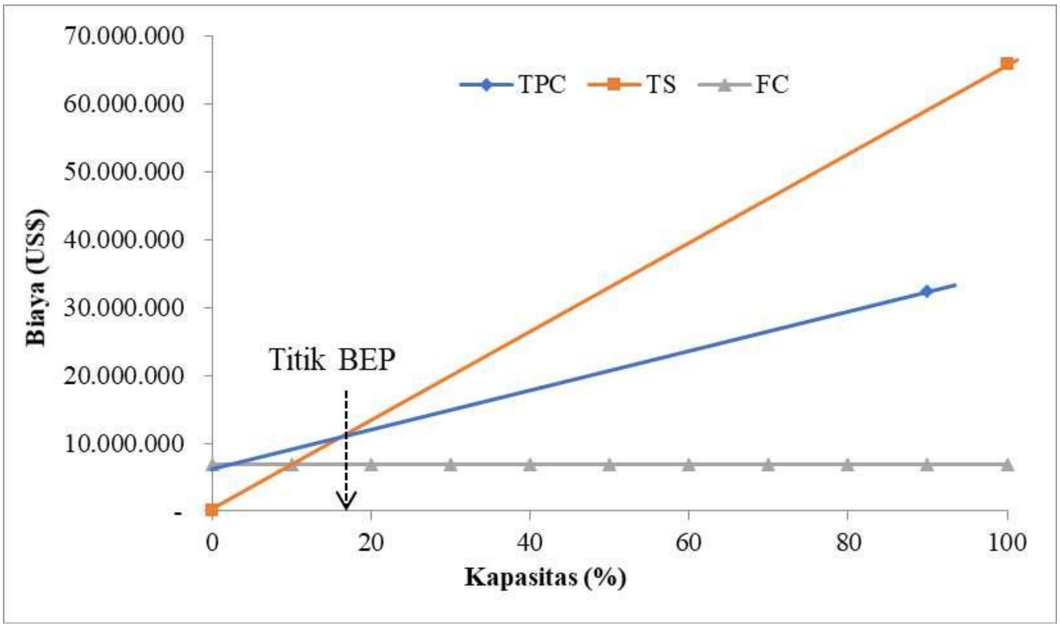
5.4 Titik Impas (*Break Event Point*)

Total Sales	= US$ 65.916.280,62 = Rp 961.748.196.625,96
Fixed Cost	= US$ 6.844.835,68 = Rp 99.869.232.793,07
Variabel Cost	= US$ 25.479.785,94 = Rp 371.761.542.703,52

$$BEP = \frac{\text{Fixed Cost}}{\text{Total Penjualan} - \text{Variabel Cost}} \times 100\%$$

$$BEP = \frac{\text{US\$ } 6.844.835,68}{\text{US\$ } 65.916.280,62 - \text{US\$ } 25.479.785,94} \times 100\%$$

BEP = 17%



Gambar D.2 Grafik *Break Event Point* (BEP)