APPENDIKS C
SPESIFIKASI PERALATAN

1. Storage Tank HCHO (F-111)

Fungsi : Untuk menyimpan HCHO selama 3 hari
tipe : Bejana tegak dengan tutup atas standart dished dan tutup bawah flat (datar)

Dasar perencanaan

suhu gudang	=	30	C	=	303,15	K
tekanan	=	1	atm	=	14,7	K
waktu tinggal	=	3	hari	=	72	jam
rate masuk	=	8663,2620	kg/jam			
	=	19082,07481	lb/jam			
	=	457969,7953	lb/hari			
Densitas	=	726,0000	kg/cm^3	=	45,3227	lb/ft^3
Bahan konstruksi	=	Stainless steell SA 240 Grade M type 316				
Penglasan	=	Double welded butt joit ,		E =	0,8	
Faktor korosi	=	1/16 in				
Allowable stress	=	18750				
Volume kosong	=	20%	volume total			
Jumlah Tangki	=	5	buah			

Perhitungan :

a. Menentukan Volume

Volume bahan baku $= \frac{m}{\rho} \times$ waktu tinggal

$$= \frac{19082,075}{45,3227} \times 72 \text{ jam}$$

$= 30313,9355\ ft^3$

menghitung volume tangki :

$$V_{tangki} = \frac{30313,9355}{5} = 6062,7871\ ft^3$$

$Vt = V_L + V_{RK}$

$= 6062,7871 + 2\%$

$= 7578,4839\ ft^3$

b. Menetukan Diameter

Diketahui : $Ls = 1,5\ di$

$V_{tangki} = V_{silinder} + V_{tutup\ atas\ SD}$

$$7578{,}4839 = \left(\frac{\pi}{4} \times di^2 \times Ls\right) + 0{,}0847\ di^3$$

$$7578{,}4839 = 1{,}1775\ di^3 + 0{,}0847\ di^3$$

$$7578{,}4839 = 1{,}2622\ di^3$$

$$di^3 = 6004{,}1862$$

$$di = 18{,}1754 \text{ ft}$$

$$218{,}10517 \text{ in}$$

c. Menentukan tinggi tangki yang terisi bahan

$$V_{tangki} = Vsilinder + V_{tutup\ atas\ SD}$$

$$6062{,}7871 = \left(\frac{\pi}{4} \times di^2 \times Lls\right) + 0{,}0847\ di^3$$

$$6062{,}7871 = \left(\frac{\pi}{4} \times 12{,}3119^2 \times Lls\right) + 0{,}0847 \times 12{,}3119^3$$

$$6062{,}7871 = \left(\frac{\pi}{4} \times 151{,}5829 \times Lls\right) + 0{,}0847 \times 1866{,}2733$$

$$6062{,}7871 = 118{,}9926\ Ls + 158{,}0733$$

$$5904{,}7138 = 118{,}9926\ Ls$$

$$Ls = 49{,}6225 \text{ ft}$$

$$= 595{,}4705 \text{ in}$$

$$Ls = 1{,}5 \times di$$

$$= 1{,}5 \times 218{,}1052$$

$$= 327{,}1578 \text{ in}$$

$$= 27{,}2631 \text{ ft}$$

d Menghitung tebal silinder

$$P_{hidrostatik} = \frac{\rho(H\text{-}1)}{144}$$

(*Brownell dan Young* pers 3.17 Hal 46)

$$= \frac{45{,}3227 \times (49{,}6225 - 1)}{144}$$

$$= 15{,}3035 \text{ psia}$$

$$Pi = P_{atm} + P_{hidrostatik}$$

$$= 14{,}7000 + 15{,}3035$$

$$= 30{,}0035 \text{ psia}$$

$$= 12{,}5926 \text{ psig}$$

tebal silinder (ts) $= \dfrac{P_i.d_i}{2(f.E- 0,6Pi)} + C$

$= \dfrac{12,5926 \times 218,1052}{2 \times [(18750 \times 0,8) - (0,6 \times 12,5926)]} + \dfrac{1}{16}$

$= \dfrac{2746,5}{226666,8} + \dfrac{1}{16}$

$= 0,0121 \times \dfrac{16}{16}$

$= \dfrac{0,1939}{16} \approx \dfrac{3}{16}$

standarisasi do

do = di + 2 ts

$= 218,1052 + \left(2 \times \dfrac{3}{16}\right)$

= 218,4802

standarisasi dengan tabel 5.7, brownell and young , hal 91

do = 240

icr = 14 0,438

r = 180

ts = 1,00

maka:

di_{baru} = do - ts

= 240 - (2 x 1,0)

= 240 - 2,0000

= 238,0000 in

= 19,8333 ft

cek hubungan Ls dengan di

Volume tangki $= \left(\dfrac{\pi}{4} \times di^2 \times Ls\right) + 0,0847\ di^3$

$7578,4839 = \left(\dfrac{3,14}{4} \times 393,3611 \times Ls\right) + 0,0847 \times 7801,6620$

$7578,4839 = 0,7850 \times 393,3611 \times Ls + 0,0847 \times 7801,6620$

$7578,4839 = 308,7885\ Ls + 660,8008$

6917,6831 = 308,7885 Ls

Ls = 22,4027 ft

$$\frac{Ls}{di} = \frac{22,4027}{19,8333} = 1,1 < 1,5 \quad (\text{ memenuhi})$$

e. Menghitung tinggi silinder

Tinggi silinder (Ls) = 1,5 di

= 1,5 x 238,0000

= 357 in

= 29,7500 ft

f Menghitung tutup atas silinder (standar dished)

$$tha = \frac{0,8850 \times Pi \times r}{f \; E - 0,1 \times Pi} + C$$

$$= \frac{0,8850 \times 12,5926 \times 180}{[(18750 \times 0,8)-(0,1 \times 12,5926)]} + \frac{1}{16}$$

$$= \frac{2006,0012}{14998,7407} + \frac{1}{16}$$

$$= 0,1337 + \frac{16}{16}$$

$$= \frac{2,1399}{16} \approx \frac{3}{16}$$

Tinggi tutup atas (ha) = 0,1690 x di baru

= 0,1690 x 238,0000

= 40,2220 in

g. Menghitung tingg storage

Tinggi storage (H) = tinggi silinder + tinggi tutup atas

= 357,0 + 40,2220

= 397,2220 in

= 33,1018 ft

Spesifikasi alat:

Nama alat	:	Storage Tank HCHO 37% sebelum masuk ke heater
Kode Alat	:	F-111
Fungsi	:	Menampung sementara HCHO 37% sebelum masuk ke heater

Type	:	Tangki silinder vertikal , tutup atas standar dished tutup bagian bawah flat (dasar)
Bahan konstruksi	:	Stainless steel SA 240 Grade M Type 316
Volume tangki	:	7578,4839 ft^3
Diameter dalam (di)	:	238,0000 in
Diameter luar (do)	:	240 in
Tebal silinder (ts)	:	3/16 in
Tinggi silinder (Ls)	:	357 in
Tebal tutup atas (tha)	:	0,1875 in
Tinggi tutup atas (ha)	:	40,2220 in
Tinggi Storange (H)	:	397,2220 in

2. Pompa Sentrifugal (L-112)

Fungsi = Untuk mengalirkan HCHO dari tangki penyimpanan (F-111) menuju heater (E-113)

Tipe = Centrifugal pump

Direncanakan =

Bahan konstruksi: = Comercial Steel

Jumlah = 1 buah

Dasar Perhitungan:

Suhu (T)	=	30 °C	=	303,150	K
Tekanan (P)	=	1 atm			
Densitas	=	726,00 g/cm^3	=	45,3227	lb/ft^3
Viscocitas	=	0,8254 Cp	=	0,00055	lb/ft.s
Rate liquid	=	19082,0748 lb/jam			

Perhitungam:

Menghitung Rate Volumetrik (Q)

$$Q = \frac{\text{Rate bahan masuk}}{\rho \text{ bahan masuk}}$$

$$= \frac{19082{,}0748}{45{,}3227}$$

$= 421{,}0269$ ft^3/jam

$= 0{,}1137$ ft^3/s

$= 51{,}0218$ gpm

$Di_{optimum} = 3{,}9 \quad Q^{0,45} \quad x \quad \rho^{0.13}$ *(Pers 15 "Petters & Timmerhaus" hal 496*

$= 3,9 \times [0,1137]^{0,45} \times [45,3227]^{0,13}$

$= 2,4068$ in

$= 0,2006$ ft

Untuk pipa ukuran 2 in sch 40

Dari *Geankoplis* , tabel A.5.1 , hal 892 didapatkan:

OD	=	2,3750	in	=	0,1979	ft
ID	=	2,0670	in	=	0,1723	ft
A	=	0,0233	ft^2			

Menentukan Kecepatan Aliran Fluida (v)

Kecepatan aliran fluida (v) $= \dfrac{Q}{A}$

$= \dfrac{421,0}{0,0233}$

$= 18060,3730$ ft/jam

$= 4,87630$ ft/s

- Menentukan Bilangan Reynold (N_{Re}) $= \dfrac{D \times v \times \rho}{\mu}$

$= \dfrac{0,1723 \times 4,8763 \times 45,3227}{0,0006}$

$= 68735,1 \geq 2100$ (aliran turbulen)

Dari *Geankoplis, fig. 2.10 Hal 88* didapatkan

Equivalent rougness (ε) = 0,00005

Relative roungness $\left[\dfrac{\varepsilon}{D}\right] = 0,0003$ *(Geankoplis, Tabel 2-10.1 Hal 94*)

Faktor friksi (f) $= \dfrac{16}{N_{Re}} = 0,00023$ *(Geankoplis, Tabel 2-10.1 Hal 94*)

- Menentukan Panjang pipa

  Asumsi:

Panjang pipa lurus	=	75 ft
elbow 90°	=	1 buah
Globe valve	=	1 buah
Tee	=	1 buah

Perhitungan:

- Panjang pipa lurus = 75 ft
- elbow 90° = 1 buah

Le/D = 75

Le = 35 ID (*Geankoplis, Tabel 2-10.1 Hal 93*)

= 35 x 0,1723 x 1 ft

= 6,0288 ft

= 1 buah

- Globe valve` = 1 buah

Le/D = 300 (wide open) (*Geankoplis, Tabel 2-10.1 Hal 93*)

Le = 13 ID

= 13 x 0,1723 x 1 ft

= 2,2393 ft

- Tee = 1 buah

Le/D = 50 ID *(Geankoplis, Tabel 2-10.1 Hal 93)*

Le = 50 x 0,1723 x 1 ft

= 8,6125 ft

Panjang pipa total (L) = Pipa lurus + elbow 90° + globe valve + tee

= 75 + 6,0288 + 2,2393 + 8,6125

= 91,8805 in

- Menentukan friksion Loss

1. Friksi pada pipa lurus

$$F_f = 4_f \frac{\Delta L}{D} \times \frac{V^2}{2g_c}$$ *(Geankoplis, Persamaan 2.10-6 Hal 86)*

$$= 4 \times 0,0030 \times \frac{75}{0,1723} \times \frac{(4,8763)^2}{2 \times 32,174}$$

$$= 4 \times 0,0030 \times 435,41 \times \frac{1931,1982}{64,348}$$

= 156,81047 lbf.ft/lbm

2. Sudden Contraction

Karena tangki sangat besar maka A_1 = 0

$$hc = 0,55 \times [1 - 0] \times \frac{(4,8763)^2}{2 \times 1 \times 32,172}$$

$$= 0{,}55 \times [1 - 0] \times \frac{(4{,}8763)^2}{2 \times 1 \times 32{,}172}$$

$$= 0{,}55 \times 1 \times \frac{1931{,}1982}{64{,}3440}$$

$= 16{,}507507$ lbl.ft/lbm

3. Sudden Expansion

$$h_{ex} = \left[1 - \frac{A2}{A1}\right] \times \frac{v_2^2}{2 \times \alpha \times gc}$$ (Geankoplis, Tabel 2.10.1 Hal 93)

$$= [1 - 0] \times \frac{(4{,}8763)^2}{2 \times 1 \times 32{,}172}$$

$$= 1 \times \frac{1931{,}1982}{64{,}3440}$$

$= 30{,}0136$ lbf.ft/lbm

4. Elbow 90°, 1 buah

Kf = 0,75 (*Geankoplis, Tabel 2.10.1 Hal 93*)

$$hf = 1\ Kf\ \frac{v_2}{2gc}$$ (*Geankoplis, Pers 2.10.1 Hal 94*)

$$= 1 \times 0{,}75\ \frac{(4{,}8763)^2}{2 \times 32{,}172}$$

$$= 1 \times 0{,}75 \times \frac{1931{,}1982}{64{,}344}$$

$= 22{,}5102$ lbf.ft/lbm

5. Tee, 1 buah

Kf = 1

$$hf = 1\ Kf\ \frac{v_2}{2gc}$$

$$= 1 \times 1\ \frac{(4{,}8763)^2}{2 \times 32{,}172}$$

$$= 1 \times \frac{23{,}7783}{64{,}3440}$$

$= 0{,}3695497$ lbf.ft/lbm

Total fraksi (∑F) = $F_f + h_c + h_{ex} + h_f$ elbow 90° + hf globe valve

Total fraksi (∑F) = 156,81047 + 16,5075 + 30,0136 + 22,5102 + 0,36955

= 225,8419 lbf.ft/lbm

e. Menentukan daya pompa

Direncanakan:

ΔZ = 30 ft

ΔP = 30 lb/ft^2

v_1 = 0 ft/detik (karena P_1=P_2)

v_2 = 4,87630 ft/detik (karena fluida diam)

$\frac{\varepsilon}{D}$ = 0,0003

Hukum Bernouli

$$\frac{\Delta P}{\rho} + \Delta Z \left[\frac{g}{gc} \right] + \frac{v_2^2}{2 \times \alpha \times gc} + (\sum F) = - Ws$$

$$0 + 30 (1) + \frac{(4,8763)^2}{2 \times 1 \times 32,172} + 225,8419 = - Ws$$

$$- Ws = 30 + \frac{23,7783}{64,3440} + 225,8419 =$$

$$- Ws = 256,21142 \text{ lbf.ft/lbm}$$

Dengan: Capacity = 51,0218 gal/menit

Dari Fig 14.36, Hal. 520, Petters & Timmerhause, didapatkan:

Efisiensi pompa (η) = 40%

$- Ws = - \eta \; Wp$

$256,2114 = - 40\% \; Wp$

$Wp = 640,52854$ ft.lb/lbm

mass flow rate (m) = Q x ρ

= 0,1137 x 45,3227

= 5,1522 lbm/s

$$WHp = Wp \times m \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

$$WHp = 640,52854 \times 5,1522 \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

WHp = 6,0002 hp

$$BHp = \frac{WHp}{\eta}$$

$$= \frac{6,0002}{40\%}$$

= 15,0005 Hp = 15 Hp

Dari Fig 14.38 Hal. 521, Petters & Timmerhause, didapatkan:

Spesifikasi Pompa Sentrifugal = 89%

$$= \frac{\text{Pump horsepower}}{\text{Efisiensi motor}}$$

$$= \frac{15,0005}{89\%}$$

= 16,8545 Hp ≈ 17 Hp

Spesifikai Pompa Sentrifugal

Fungsi		:	Untuk mengalirkan HCHO menuju heater (E-113)				
Kode alat		:	L-112				
Tipe		:	Centrifugal pump				
kapasitaas		:	51,0218 gpm				
Suhu Operasi		:	303,150 K				
Tekanan Operasi		:	1 atm				
Efisiensi Pompa		:	89%				
ΔP		:	30 lb/ft²				
Dimensi	NPS	:	2 in	OD :	2,3750	A :	0,0233
	Sch	:	40	ID :	2,0670		

3. Storage Tank NaOH 50% (F-114)

Fungsi : untuk menyimpan NaOH selama 3 hari

tipe : Bejana tegak dengan tutup atas standart dished dan tutup bawah flat (datar)

Dasar perencanaan

suhu gudang	=	30	C	=	303,15	K
tekanan	=	1	atm	=	14,7	K
waktu tinggal	=	3	hari	=	72	jam
kapasitas	=	11707,1108	kg/jam			
	=	25786,5876	lb/jam			
	=	618878,1018	lb/hari			
Densitas	=	1,71	gr/cm³	=	106,7518	lb/ft³
Bahan konstruksi	=	Stainless steell SA 240 Grade M type 316				
Penglasan	=	Double welded butt joit ,	E	=	0,8	
Faktor korosi	=	1/16 in				

Allowable stress = 18750
Volume kosong = 20% volume total
Jumlah Tangki = 2 buah

Perhitungan :

a. Menentukan Volume

Volume bahan baku $= \frac{m}{\rho} \times$ waktu tinggal

$= \frac{25786,588}{106,7518} \times 72$ jam

$= 17392,0635\ ft^3$

karena volunme yang dihasilkan sangat besar ,
maka tangki yang dibuat dirancang menjadi 4 buah :

$V_{tangki} = \frac{17392,064}{2} = 8696,0318\ ft^3$

$Vt = V_L + V_{RK}$
$= 8696,0318 + 2\%$
$= 10870,0397\ ft^3$

b. Menetukan Diameter

Diketahui : Ls = 1,5 di

$V_{tangki} = V_{silinder} + V_{tutup\ atas\ SD}$

$10870,0397 = \left(\frac{\pi}{4} \times di^2 \times Ls\right) + 0,0847\ di^3$

$10870,0397 = 1,1775\ di^3 + 0,0847\ di^3$

$10870,0397 = 1,2622\ di^3$

$di^3 = 8611,9788$

$di = 20,4975$ ft
245,97005 in

c. Menentukan tinggi tangki yang terisi bahan

$V_{tangki} = Vsilinder + V_{tutup\ atas\ SD}$

$8696,0318 = \left(\frac{\pi}{4} \times di^2 \times Lls\right) + 0,0847\ di^3$

$8696,0318 = \left(\frac{\pi}{4} \times 18,6174^2 \times Lls\right) + 0,0847 \times 18,7174^3$

$8696,0318 = \left(\frac{\pi}{4} \times 346,608 \times Lls\right) + 0,0847 \times 6452,932$

$8696{,}0318 = 272{,}087 \; Lls + 546{,}56334$

$8149{,}4684 = 272{,}087 \; Lls +$

$Lls = 29{,}9517 \; ft$

$= 359{,}4205 \; in$

$Ls = 1{,}5 \times di$

$= 1{,}5 \times 245{,}9701$

$= 368{,}9551 \; in$

$= 30{,}7463 \; ft$

d Menghitung tebal silinder

$$P_{hidrostatik} = \frac{\rho(H-1)}{144}$$

(Brownell dan Young pers 3.17 Hal 46)

$$= \frac{106{,}7518 \times (29{,}952 - 1)}{144}$$

$= 21{,}4628 \; psia$

$Pi = P_{atm} + P_{hidrostatik}$

$= 14{,}7000 + 21{,}4628$

$= 36{,}1628 \; psia$

$= 12{,}5926 \; psig$

$$\text{tebal silinder (ts)} = \frac{P_i . d_i}{2(f.E - 0{,}6Pi)} + C$$

$$= \frac{12{,}5926 \times 245{,}9701}{2 \times [(18750 \times 0{,}8) - (0{,}6 \times 12{,}5926} + \frac{1}{16}$$

$$= \frac{3097{,}4}{226666{,}8} + \frac{1}{16}$$

$$= 0{,}0137 \times \frac{16}{16}$$

$$= \frac{0{,}2186}{16} \approx \frac{3}{16}$$

standarisasi do

$do = di + 2 \; ts$

$$= 245{,}9701 + \left(2 \times \frac{3}{16}\right)$$

= 246,3451

standarisasi dengan tabel 5.7, brownell and young , hal 91

do = 262

icr = 14 0,438

r = 180

ts = 1,00

maka:

di_{baru} = do - ts

= 262 - (2 x 1,0)

= 262 - 1,750

= 260,3 in

= 21,6875 ft

cek hubungan Ls dengan di

$$\text{Volume tangki} = \left(\frac{\pi}{4} \times di^2 \times Ls\right) + 0{,}0847\ di^3$$

$$10870{,}0397 = \left(\frac{3{,}14}{4} \times 470{,}3477 \times Ls\right) + 0{,}0847 \times 10200{,}6648$$

$$10870{,}0397 = 0{,}7850 \times 470{,}3477 \times Ls + 0{,}0847 \times 10200{,}6648$$

$$10870{,}0397 = 369{,}2229\ Ls + 863{,}9963$$

$$10006{,}0434 = 369{,}2229\ Ls$$

$$Ls = 27{,}1003\ \text{ft}$$

$$\frac{Ls}{di} = \frac{27{,}1003}{21{,}6875} = 1{,}2 \quad < 1{,}5 \ \text{(memenuhi)}$$

e. Menghitung tinggi silinder

Tinggi silinder (Ls) = 1,5 di

= 1,5 x 260,2500

= 390 in

= 32,5313 ft

f Menghitung tutup atas silinder (standar dished)

$$tha = \frac{0{,}8850 \times Pi \times r}{f\ E - 0{,}1 \times Pi} + C$$

$$= \frac{0{,}8850 \times 12{,}5926 \times 180}{[(18750 \times 0{,}8) - (0{,}1 \times 12{,}5926)]} + \frac{1}{16}$$

$$= \frac{2006{,}0012}{14998{,}7407} + \frac{1}{16}$$

$$= 0{,}1337 + \frac{16}{16}$$

$$= \frac{2{,}1399}{16} \approx \frac{3}{16}$$

Tinggi tutup atas (ha) = 0,1690 x di baru
= 0,1690 x 260,2500
= 43,9823 in

g. Menghitung tingg storage

Tinggi storage (H) = tinggi silinder + tinggi tutup atas
= 390,4 + 43,9823
= 434,3573 in
= 36,1964 ft

Spesifikasi alat:

Nama alat	:	Storage Tank NaOH 50%
Kode Alat	:	F-114
Fungsi	:	Menampung sementara NaOH 50% sebelum masuk keheater
Type	:	Tangki silinder vertikal , tutup atas standar dished tutp bagian bawah flat (dasar)
Bahan konstruksi	:	Stainless steel SA 240 Grade M Type 316
Volume tangki	:	10870,0397 ft^3
Diameter dalam (di)	:	260,2500 in
Diameter luar (do)	:	262 in
Tebal silinder (ts)	:	1 in
Tinggi silinder (Ls)	:	390 in
Tebal tutup atas (tha)	:	3/16 in
Tinggi tutup atas (ha)	:	43,9823 in
Tinggi Storange (H)	:	434,3573 in

4. Pompa Sentrifugal (L-115)

Fungsi = Untuk mengalirkan NaOH dari tangki penyimpanan (F-114) menuju heater (E-116)

Tipe = Centrifugal pump

Direncanakan =
Bahan konstruksi: = Comercial Steel
Jumlah = 1 buah

Dasar Perhitungan:
Suhu (T) = 30 ℃ = 303,150 K
Tekanan (P) = 1 atm
Rate liquid = 11707,1108 kg/jam
= 25809,5 lb/jam
viscositas NaOH = 1,9 cP = 0,0012701 lb/ft.s
Perhitungam:
Menghitung Rate Volumetrik (Q)

$$Q = \frac{\text{Rate bahan masuk}}{\rho\ \text{bahan masuk}}$$

$$= \frac{25809{,}4964}{106{,}7518}$$

= 241,7710 ft³/jam
= 0,0653 ft³/s
= 29,2988 gpm

$Di_{optimum} = 3{,}9\ Q^{0,45} \times \rho^{0.13}$ *(Pers 15 "Petters & Timmerhaus" hal 496)*

$= 3{,}9 \times [\ 0{,}0653\ ]^{0,45} \times [\ 106{,}7518\ ]^{0,13}$

= 2,0960 in
= 0,1747 ft

Untuk pipa ukuran 2 in sch 80
Sehingga: *Geankoplis* , tabel A.5.1 , hal 892 didapatkan:

OD	=	2,3750	in	=	0,1979	ft
ID	=	1,9390	in	=	0,1616	ft
A	=	0,0205	ft²			

c. Menentukan Kecepatan Aliran Fluida (v)

$$\text{Kecepatan aliran fluida (v)} = \frac{Q}{A}$$

$$= \frac{241{,}8}{0{,}0205}$$

= 11785,4589 ft/jam
= 3,18207 ft/s

- Menentukan Bilangan Reynold (N_{Re}) = $\frac{D \times v \times \rho}{\mu}$

$= \frac{0,1616 \times 3,1821 \times 106,7518}{0,0013}$

$= 43216,6 \geq 2100$ (aliran turbulen)

Dari *Geankoplis, fig. 2.10 Hal 88* didapatkan

Equivalent rougness (ε) = 0,00005

Relative roungness $[\frac{\varepsilon}{D}]$ = 0,0003 *(Geankoplis, Tabel 2-10.1 Hal 94*)

Faktor friksi (f) = $\frac{16}{N_{Re}}$ = 0,00037 *(Geankoplis, Tabel 2-10.1 Hal 94*)

- Menentukan Panjang pipa

Asumsi:

Panjang pipa lurus = 75 ft

elbow 90° = 1 buah

Globe valve = 1 buah

Tee = 1 buah

Perhitungan:

- Panjang pipa lurus = 75 ft
- elbow 90° = 1 buah

Le/D = 75

Le = 35 ID (*Geankoplis, Tabel 2-10.1 Hal 93*)

= 35 x 0,1616 x 1 ft

= 5,6554 ft

= 1 buah

- Globe valve = 1 buah

Le/D = 13 (*Geankoplis, Tabel 2-10.1 Hal 93*)

Le = 13 ID

= 13 x 0,1616 x 1 ft

= 2,1006 ft

- Tee = 1 buah

Le/D = 50 ID *(Geankoplis, Tabel 2-10.1 Hal 93)*

Le = 50 x 0,1616 x 1 ft

= 8,0792 ft

Panjang pipa total (L) = Pipa lurus + elbow 90° + globe valve + tee
= 75 + 5,6554 + 2,1006 + 8,0792
= 90,8352 ft

- Menentukan friksion Loss
  1. Friksi pada pipa lurus

$$F_f = 4_f \frac{\Delta L}{D} \times \frac{V^2}{2g_c}$$ *(Geankoplis, Persamaan 2.10-6 Hal 86)*

$$= 4 \times 0,0030 \times \frac{75}{0,1616} \times \frac{(3,1821)^2}{2 \times 32,174}$$

$$= 4 \times 0,0030 \times 464,16 \times \frac{1931,1982}{64,348}$$

$$= 167,16207 \text{ lbf.ft/lbm}$$

  2. Sudden Contraction

Karena tangki sangat besar maka A_1 = 0

$$hc = 0,55 \times [1 - 0] \times \frac{(3,1821)^2}{2 \times 1 \times 32,172}$$

$$= 0,55 \times [1 - 0] \times \frac{(3,1821)^2}{2 \times 1 \times 32,172}$$

$$= 0,55 \times 1 \times \frac{1931,1982}{64,3440}$$

$$= 16,507507 \text{ lbl.ft/lbm}$$

  3. Sudden Expansion

$$h_{ex} = \left[1 - \frac{A2}{A1}\right] \times \frac{v_2^2}{2 \times \alpha \times gc}$$ (*Geankoplis, Persamaan 2.10-15 Hal 93*)

$$= [1 - 0] \times \frac{(3,1821)^2}{2 \times 1 \times 32,172}$$

$$= 1 \times \underline{1931,1982}$$

$$= 1 \times \frac{1931,1982}{64,3440}$$

$$= 30,0136 \text{ lbf.ft/lbm}$$

  4. Elbow 90°, 1 buah

Kf = 0,75 (*Geankoplis, Tabel 2.10.1 Hal 93*)

$$hf = 1Kf \frac{v_2}{2gc}$$ (*Geankoplis, Pers 2.10.1 Hal 94*)

$$= 1 \times 0,75 \underline{(3,1821)^2}$$

$$= 1 \times 0{,}75 \times \frac{1931{,}1982}{64{,}344} \quad (2 \times 32{,}172)$$

$= 22{,}5102$ lbf.ft/lbm

5. Tee, 1 buah

Kf = 1

$$hf = 1\ Kf\ \frac{v_2}{2gc}$$

$$= 1 \times \frac{1\ (3{,}1821)^2}{2 \times 32{,}172}$$

$$= 1 \times \frac{10{,}1256}{64{,}3440}$$

$= 0{,}1573666$ lbf.ft/lbm

Total fraksi (∑F) = $F_f + h_c + h_{ex} + h_f$ elbow 90° + hf globe valve

Total fraksi (∑F) = 167,16207 + 16,5075 + 30,0136 + 22,5102 + 0,1573666

= 236,3508 lbf.ft/lbm

e. Menentukan daya pompa

Direncanakan:

ΔZ = 30 ft

ΔP = 30 lb/ft^2

v_1 = 0 ft/detik (karena P_1=P_2)

v_2 = 3,18207 ft/detik (karena fluida diam)

$\frac{\varepsilon}{D}$ = 0,0003

Hukum Bernouli

$$\frac{\Delta P}{\rho} + \Delta Z \left[\frac{g}{gc} \right] + \frac{v_2^2}{2 \times \alpha \times gc} + (\sum F) = - Ws$$

$$0 + 30\ (1) + \frac{(3{,}1821)^2}{2 \times 1 \times 32{,}172} + 236{,}3508 = - Ws$$

$$- Ws = 30 + \frac{10{,}1256}{64{,}3440} + 236{,}3508 =$$

$- Ws = 266{,}50819$ lbf.ft/lbm

Dengan: Capacity = 29,2988 gal/menit

Dari Fig 14.36, Hal. 520, Petters & Timmerhause, didapatkan:

Efisiensi pompa (η) = 40%

$- Ws = - \eta \; Wp$

$266{,}5082 = - 40\% \; Wp$

$Wp = 666{,}27048$ ft.lb/lbm

mass flow rate (m) = Q x ρ

= 0,0653 x 106,7518

= 6,9686 lbm/s

$WHp = Wp \times m \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$

$WHp = 666{,}27048 \times 6{,}9686 \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$

WHp = 8,4417 hp

$BHp = \frac{WHp}{\eta}$

$= \frac{8{,}4417}{40\%}$

= 21,1043 Hp = 21 Hp

Dari Fig 14.38 Hal. 521, Petters & Timmerhause, didapatkan:

Spesifikasi Pompa Sentrifugal = 89%

$= \frac{\text{Pump horsepower}}{\text{Efisiensi motor}}$

$= \frac{21{,}1043}{89\%}$

= 23,7127 Hp ≈ 24 Hp

Spesifikai Pompa Sentrifugal

Fungsi	:	Untuk mengalirkan NaOH menuju heater				
Kode alat	:	L-115				
Tipe	:	Centrifugal pump				
kapasitaas	:	29,2988 gpm				
Suhu Operasi	:	303,150 K				
Tekanan Operasi	:	1 atm				
Efisiensi Pompa	:	89%				
ΔP	:	30 lb/ft²				
Dimensi NPS	:	2 in	OD :	2,3750	A :	0,0205
Sch	:	80	ID :	1,9390		

5. Storage C_2H_4O 98% (F-117)

Fungsi : Menyimpan C_2H_4O selama 7 hari

Tipe : Bejana tegak dengan tutup atas standart dishes dan tutup bawah flat (datar)

Direncanakan :

Suhu	:	30	˚C	=	303,15	K
Tekanan Operasi	:	1	atm	=	14,7	psia
Rate masuk	:	23180,0793	kg/jam	=	51102,80283	lb/jam
				=	1226467,268	lb/hari
Densitas	:	0,548	gr/cm^3	=	34,2105	lb/ft^3
Waktu tinggal	:	7	hari	=	168	jam
Bahan konstruksi	:	Stainless steel SA 240 Grade M Type 316				
Pengelasan	:	Double welded butt joint	E	=	0,8	
Faktor korosi	:	1/16	in			
Allowable stress	:	18750				
Volume kosong	:	20%	volume total			
Jumlah Tangki	:	2	buah			

Perhitungan :

a. Menentukan Volume

Volume bahan baku : $\dfrac{m}{\rho} \times$ waktu tinggal

$: \dfrac{51102,8028}{34,2105} \times 168 \text{ jam}$

$: 250954,1005 \ ft^3$

volume liquid : $\dfrac{250954,1005}{2} = 125477,0502 \ ft^3$

$V_T : V_L + V_{RK}$

$: 125477,0502 + 0,2 \ V_T$

$: 156846,3128 \ ft^3$

b. Menentukan Diameter

Diketahui : $Ls = 1,5 \ di$

$V_{tangki} = V_{silinder} + V_{tutup\ atas\ SD}$

$$156846,3128 = \left(\frac{\pi}{4} \times di^2 \times Ls\right) + 0,0847 \ di^3$$

$$156846,3128 = 1,1775 \ di^3 + 0,0847 \ di^3$$

$$156846{,}3128 = 1{,}2622 \; di^3$$
$$di^3 = 124264{,}2314$$
$$di = 49{,}9017 \text{ ft}$$
$$= 598{,}8205 \text{ in}$$

c. Menentukan tinggi tangki yang terisi bahan

$$V_{tangki} = V_{silinder} + V_{tutup\ atas\ SD}$$
$$125477{,}0502 = \left(\frac{\pi}{4} \times di^2 \times Lls\right) + 0{,}0847 \; di^3$$
$$125477{,}0502 = \left(\frac{\pi}{4} \times 49{,}9017^2 \times Lls\right) + 0{,}0847 \times 49{,}9017$$
$$125477{,}0502 = 1954{,}7914 \; Lls + 10525{,}180$$
$$114951{,}8699 = 1954{,}7914 \; Lls$$
$$Lls = 58{,}8052 \text{ ft}$$
$$= 705{,}6622 \text{ in}$$

$$Ls = 1{,}5 \times di$$
$$= 1{,}5 \times 598{,}8205$$
$$= 898{,}2307 \text{ in}$$
$$= 74{,}8526 \text{ ft}$$

d. Menghitung tebal silinder

$$P_{hidrostatik} = \frac{\rho\,(H-1)}{144}$$ (Brownell dan Young pers. 3.17 Hal 46)
$$= \frac{34{,}2105 \times (74{,}8526 - 1)}{144}$$
$$= 17{,}5454 \text{ psia}$$
$$Pi = P_{atm} + P_{hidrostatik}$$
$$= 14{,}6959 + 17{,}5454$$
$$= 32{,}2413 \text{ psia}$$
$$= 17{,}5413 \text{ psig}$$

tebal silinder (ts)
$$= \frac{Pi.di}{2(f.E - 0{,}6Pi)} + C$$
$$= \frac{17{,}5413 \times 598{,}8205}{2 \times [(18750 \times 0{,}8000) - (0{,}6 \times 17{,}541)]} + \frac{1}{16}$$
$$= 0{,}4129 \times \frac{1}{16}$$

$$= \frac{0,4129}{16} \approx \frac{3}{16}$$

Standarisasi do

do = di + 2 ts

$$= 598,820 + \left(2 \times \frac{3}{16}\right)$$

= 599,195 in

\

do = 240

icr = 14 0,438

r = 180

ts = 1,00

maka :

di_{baru} = do - ts

= 599,195 - (2 × 1,0000)

= 597,1955 in

= 49,7663 ft

Cek hubungan Ls dengan di:

$$\text{Volume tangki} = \left(\frac{\pi}{4} \times di^2 \times Ls\right) + 0,0847 \; di^3$$

$$156846,3128 = \left(\frac{3,14}{4} \times 49,7663^2 \times Ls\right) + 0,0847 \times 49,766$$

156846,3128 = 1944,1965 Ls + 10439,7272

146406,5856 = 1944,1965 Ls

Ls = 75,3044 ft

$$\frac{Ls}{di} = \frac{75,3044}{49,7663} = 1,5 < 1,5 \text{ (memenuhi)}$$

e. Menghitung tinggi silinder

Tinggi silinder (Ls) = 1.5 di

= 1,5 × 597,1955

= 895,793 in

= 74,6494 ft

f. Menghitung tutup atas silinder (standar dished)

$$tha = \frac{0,8850 \times Pi \times r}{f. E - 0.1. Pi} + C$$

$$= \frac{0,8850 \times 17,5413 \times 0}{[(18750 \times 0,8)-(0,1 \times 17,5413)]} + \frac{1}{16}$$

$$= \frac{0,0000}{14998,2459} + \frac{1}{16}$$

$$= 0,0625 \times \frac{16}{16}$$

$$= \frac{1,0000}{16} \approx \frac{3}{16}$$

Tinggi tutup atas (ha) = 0,169 x di baru
= 0,169 x 597,20
= 100,9260 in

g. Menghitung tinggi storage

Tinggi storage (H) = tinggi silinder + tinggi tutup atas
= 895,793 + 100,9260
= 996,7192 in
= 83,0599 ft

Spesifikasi alat :

Nama alat	:	Storage C_2H_4O 98% (F-117)
Fungsi	:	Menampung sementara C_2H_4O 98%sebelum masuk ke dalam heater (E-113)
Type	:	Tangki silinder vertikal, tutup atas standar dished tutup bagian bawah flat (dasar)
Bahan konstruksi	:	Stainless steel SA 240 Grade M Type 316
Volume tangki	:	156846,3128 ft^3
Diameter dalam (di)	:	597,1955 in
Diameter luar (do)	:	0 in
Tebal silinder (ts)	:	0,0000 in
Tinggi silinder (Ls)	:	895,7932 in
Tebal tutup atas (tha)	:	3/16 in
Tinggi tutup atas (ha)	:	100,9260 in
Tinggi Storage (H)	:	996,7192 in

6. Pompa Sentrifugal (L-118)

Fungsi = Untuk mengalirkan C_2H_4O dari tangki penyimpanan (F-117) menuju heater (E-119)

Tipe = Centrifugal pump

Direncanakan =

Bahan konstruksi: = Comercial Steel

Jumlah = 1 buah

Dasar Perhitungan:

Suhu (T)	=	30	°C	=	303,150	K
Tekanan (P)	=	1	atm			
Densitas	=	0,55	g/cm³	=	34,2105	lb/ft³
Viscocitas	=	0,7000	Cp	=	0,00047	lb/ft.s
Rate liquid	=	51102,8028	lb/jam			

Perhitungam:

Menghitung Rate Volumetrik (Q)

$$Q = \frac{\text{Rate bahan masuk}}{\rho \text{ bahan masuk}}$$

$$= \frac{51102,8028}{34,2105}$$

= 1493,7744 ft³/jam

= 0,4033 ft³/s

= 181,0217 gpm

$Di_{optimum}$ = 3,9 $Q^{0,45}$ x $\rho^{0.13}$ *(Pers 15 "Petters & Timmerhaus" hal 496)*

= 3,9 x $[\ 0,4033\ ]^{0,45}$ x $[\ 34,2105\ ]^{0,13}$

= 4,1025 in

= 0,3419 ft

Untuk pipa ukuran 4 in sch 40

Dari *Geankoplis* , tabel A.5.1 , hal 892 didapatkan:

OD	=	4,5000	in	=	0,3750	ft
ID	=	4,0260	in	=	0,3355	ft
A	=	0,0884	ft²			

Menentukan Kecepatan Aliran Fluida (v)

$$\text{Kecepatan aliran fluida (v)} = \frac{Q}{A}$$

$$= \frac{1493,8}{0,0884}$$

= 16890,2204 ft/jam

= 4,56036 ft/s

- Menentukan Bilangan Reynold (N_{Re}) = $\frac{D \times v \times \rho}{\mu}$

$$= \frac{0,3355 \times 4,5604 \times 34,2105}{0,0005}$$

= 111437,3 ≥ 2100 (aliran turbulen)

Dari *Geankoplis, fig. 2.10 Hal 88* didapatkan

Equivalent rougness (ε) = 0,00005

Relative roungness $\left[\frac{\varepsilon}{D} \right]$ = 0,0001 *(Geankoplis, Tabel 2-10.1 Hal 94*)

Faktor friksi (f) = $\frac{16}{N_{Re}}$ = 0,00014 *(Geankoplis, Tabel 2-10.1 Hal 94*)

- Menentukan Panjang pipa

Asumsi:

Panjang pipa lurus = 75 ft

elbow 90° = 1 buah

Globe valve = 1 buah

Tee = 1 buah

Perhitungan:

- Panjang pipa lurus = 75 ft
- elbow 90° = 1 buah

Le/D = 75

Le = 35 ID (*Geankoplis, Tabel 2-10.1 Hal 93*)

= 35 x 0,3355 x 1 ft

= 11,7425 ft

= 1 buah

- Globe valve` = 1 buah

Le/D = 300 (wide open) (*Geankoplis, Tabel 2-10.1 Hal 93*)

Le = 13 ID

= 13 x 0,3355 x 1 ft

= 4,3615 ft

- Tee = 1 buah

  Le/D = 50 ID *(Geankoplis, Tabel 2-10.1 Hal 93)*

  Le = 50 x 0,3355 x 1 ft

  = 16,7750 ft

Panjang pipa total (L) = Pipa lurus + elbow 90° + globe valve + tee

= 75 + 11,7425 + 4,3615 + 16,7750

= 107,8790 in

- Menentukan friksion Loss

1. Friksi pada pipa lurus

$$F_f = 4_f \frac{\Delta L}{D} x \frac{V^2}{2g_c}$$ *(Geankoplis, Persamaan 2.10-6 Hal 86)*

$$= 4 \text{ x } 0,0030 \text{ x } \frac{75}{0,3355} \text{ x } \frac{(4,5604)^2}{2 \text{ x } 32,174}$$

$$= 4 \text{ x } 0,0030 \text{ x } 223,55 \text{ x } \frac{1931,1982}{64,348}$$

= 80,508507 lbf.ft/lbm

2. Sudden Contraction

Karena tangki sangat besar maka A_1 = 0

$$hc = 0,55 \text{ x } [\ 1 - 0\ ] \text{ x } \frac{(4,5604)^2}{2 \text{ x } 1 \text{ x } 32,172}$$

$$= 0,55 \text{ x } [\ 1 - 0\ ] \text{ x } \frac{(4,5604)^2}{2 \text{ x } 1 \text{ x } 32,172}$$

$$= 0,55 \text{ x } 1 \text{ x } \frac{1931,1982}{64,3440}$$

= 16,507507 lbl.ft/lbm

3. Sudden Expansion

$$h_{ex} = \left[\ 1 - \frac{A2}{A1}\ \right] \text{ x } \frac{v_2^2}{2 \text{ x } \alpha \text{ x } gc}$$ (Geankoplis, Tabel 2.10.1 Hal 93)

$$= [\ 1 - 0\ ] \text{ x } \frac{(4,5604)^2}{2 \text{ x } 1 \text{ x } 32,172}$$

$$= 1 \text{ x } \frac{1931,1982}{64,3440}$$

= 30,0136 lbf.ft/lbm

4. Elbow 90°, 1 buah

Kf = 0,75 (*Geankoplis, Tabel 2.10.1 Hal 93*)

hf = 1 Kf $\frac{v_2}{2gc}$ (*Geankoplis, Pers 2.10.1 Hal 94*)

$= 1 \times \frac{0{,}75\ (4{,}5604)^2}{2 \times 32{,}172}$

$= 1 \times 0{,}75 \times \frac{1931{,}1982}{64{,}344}$

= 22,5102 lbf.ft/lbm

5. Tee, 1 buah

Kf = 1

hf = 1 Kf $\frac{v_2}{2gc}$

$= 1 \times \frac{1\ (4{,}5604)^2}{2 \times 32{,}172}$

$= 1 \times \frac{20{,}7969}{64{,}3440}$

= 0,323214 lbf.ft/lbm

Total fraksi (∑F) = $F_f + h_c + h_{ex} + h_f$ elbow 90° + hf globe valve

Total fraksi (∑F) = 80,508507 + 16,5075 + 30,0136 + 22,5102 + 0,323214

= 149,5399 lbf.ft/lbm

e. Menentukan daya pompa

Direncanakan:

ΔZ = 30 ft

ΔP = 30 lb/ft^2

v_1 = 0 ft/detik (karena $P_1=P_2$)

v_2 = 4,56036 ft/detik (karena fluida diam)

$\frac{\varepsilon}{D}$ = 0,0001

Hukum Bernouli

$$\frac{\Delta P}{\rho} + \Delta Z \left[\frac{g}{gc}\right] + \frac{v_2^2}{2 \times \alpha \times gc} + (\textstyle\sum F) = -\ Ws$$

$$0 + 30\ (1) + \frac{(4{,}5604)^2}{2 \times 1 \times 32{,}172} + 149{,}5399 = -\ Ws$$

$$- Ws = 30 + \frac{20,7969}{64,3440} + 149,5399 =$$

$$- Ws = 179,86311 \text{ lbf.ft/lbm}$$

Dengan: Capacity = 181,0217 gal/menit

Dari Fig 14.36, Hal. 520, Petters & Timmerhause, didapatkan:

Efisiensi pompa (η) = 40%

$$- Ws = - \eta \; Wp$$

$$179,8631 = - 40\% \; Wp$$

$$Wp = 449,65778 \text{ ft.lb/lbm}$$

$$\text{mass flow rate (m)} = Q \times \rho$$

$$= 0,4033 \times 34,2105$$

$$= 13,7978 \text{ lbm/s}$$

$$WHp = Wp \times m \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

$$WHp = 449,65778 \times 13,7978 \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

$$WHp = 11,2805 \text{ hp}$$

$$BHp = \frac{WHp}{\eta}$$

$$= \frac{11,2805}{40\%}$$

$$= 28,2012 \text{ Hp} = 28 \text{ Hp}$$

Dari Fig 14.38 Hal. 521, Petters & Timmerhause, didapatkan:

Spesifikasi Pompa Sentrifugal = 89%

$$= \frac{\text{Pump horsepower}}{\text{Efisiensi motor}}$$

$$= \frac{28,2012}{89\%}$$

$$= 31,6868 \text{ Hp} \approx 32 \text{ Hp}$$

Spesifikai Pompa Sentrifugal

Fungsi	:	Untuk mengalirkan HCHO menuju heater (E-119)
Kode alat	:	L-118
Tipe	:	Centrifugal pump
kapasitaas	:	181,0217 gpm
Suhu Operasi	:	303,150 K

Tekanan Operasi	:	1 atm				
Efisiensi Pompa	:	89%				
ΔP	:	30 lb/ft²				
Dimensi NPS	:	4 in	OD :	4,5000	A :	0,0884
Sch	:	40	ID :	4,0260		

7. Heater (E-113)

Fungsi : Untuk memanaskan HCHO 37% sebelum masuk Reaktor (R-110)

Tipe : Double pipe Heat exchanger

Direncanakan:

- faktor kekotoran gabungan minimum (Rd) = 0,0025 jam. Ft² (*kern* , Halaman 107)
- penurunan tekanan aliran maksimum (Δp) = 10 psi
- ΔP maksimum steam = 2 psi
- Digunakan pipa ukuran 1 in
- pipa : Steam
- Anulus : HCHO

Dasar perencanaan:

Dari Appendix B dan C didapatkan data sebagai berikut:

- Masssa bahan masuk (M) = 23414,222 kg/jam
  = 51618,993 lb/jam
  =
- Suhu bahan masuk (t_1) = 30 °C = 86 °F = 303,15 K
- Suhu bahan keluar (t_2) = 60 °C = 140 °F = 333,2 K
- Kebutuhan steam (m) = 494,79197 kg/jam
  = 1090,818 lb/jam
- Panas yang dibawah steam = 25011,159 kj/jam
  = 23706,001 btu/jam
- steam masuk pada suhu (T_1) = 130 °C = 266 °F
- Steam keluar pada suhu (T_2) = 130 °C = 266 °F
- Beban Panas = 1075479,8186 = 426506,908 Btu/jam
- Pipa = Steam
- Anulus = HCHO

Perhitungan

A. Menghitung Δt

$\Delta t_1 = T_1 - t_2 = 266 - 140$ °F = 126 °F

$\Delta t_2 = T_2 - t_1 = 266 - 86$ °F = 180 °F

$$\Delta T_{LM} = \frac{\Delta t_1 - \Delta t_2}{\ln \Delta t_1 / \Delta t_2}$$

$$= \frac{126 - 180}{\ln \frac{126}{180}}$$

= 151,3984 °F

B. Menghitung suhu Kalorik (T_c dan t_c)

Tc = $(T_1 + T_2)/2$ = 266 °F = 130 ℃

tc = (t1 + t2)/2 = 156 °F = 69 ℃

$$= \frac{130 - 69}{\ln \frac{130}{69}}$$

= 96,2320 °F

C. Trial U_D

- Asumsi UD = 100,0000 Btu/jam.ft².°F

$$A = \frac{Q}{U_d \cdot \Delta t}$$

$$= \frac{426.506,9077 \text{ Btu/jam}}{100,0000 \text{ Btu/jam.ft}^2.°\text{F} \times 96,23 \text{ °F}}$$

= 44,3207 ft²

D Trial ukuran double pipe:

dicoba ukuran double pipe 2 1/2 'x 1 1/4" IPS sec. 40 dengan aliran steam

Bagian pipa anulus (Kern tabel 6.2 ha 110)

a_{an}	=	2,63	in^2	=	0,0183	ft^2
de	=	2,02	in	=	0,1683	ft
de'	=	0,81	in	=	0,0675	ft

Bagian Pipa (Kern, tabel 11 hal 844)

ap	=	1,5	in^2	=	0,0104	ft^2
di	=	1,38	in	=	0,1150	ft
do	=	1,66	in	=	0,1383	ft
a"	=	0,435	ft^2/ft	=		

Evaluasi Perpindahan Panas

Annulus, HCHO

1. Menghitung Nre anulus

$$Gaan = \frac{m}{a_{an}}$$

$$= \frac{51618{,}993 \text{ lb/jam}}{0{,}0183 \text{ ft}^2}$$

$$= 2826287{,}1 \text{ lb/jam.ft}^2$$

μ pada tc = 86 °F

μ = 0,497 Cp

(fig.24"kern",hal 834)

$$N_{Re} = \frac{G_{AA} \times di}{\mu \times 2{,}42}$$

$$= \frac{2826287{,}1 \times 0{,}1683}{0{,}4970 \times 2{,}42}$$

$$= 395562{,}07$$

2. JH = 56 (fig 24" kern" hal 834
3. Menghitung harga koefisien film

Cp = 0,9989 Btu/lb°F

k = 0,356 Btu/jam.ft²°F/ft

$$\left(\frac{Cp\ \mu}{k}\right)^{1/3} = \left(\frac{1{,}00 \times 0{,}5}{0{,}3560}\right)^{1/3}$$

$$= 1{,}1172$$

$$ho = \frac{Jh \times K \times}{De}\left(\frac{Cp.\mu}{k}\right)^{1/3}$$

$$= 132{,}31549$$

$$\frac{ho}{\varphi s} = 372 \text{ Btu/jam ft}^2\text{°F}$$

Hot fluida,inner pipe ,steam

1. Menghitung N_{Re} pipa

$$G_p = \frac{m}{a_p}$$

$$= \frac{426506{,}9077 \text{ lb/jam}}{0{,}0104 \text{ ft}^2}$$

$$= 40944663{,}1430 \text{ lb/jam ft2}$$

μ pada T_c = 266 °F

= 0,112 cp

(Geankoplis, tabel A.2-4, hal 855)

$$NRe_p = \frac{G_p \times di}{\mu \times 2{,}42}$$

$$= \frac{40944663{,}1430 \times 0{,}1150}{0{,}1120 \times 2}$$

$$= 17372477{,}3519$$

2. JH = 20 (fig 24" kern" hal 834
3. Menghitung harga koefisien film

Cp = 0,234 Btu/lb°F

k = 0,356 Btu/jam.ft²°F/ft

3. Harga koefisien perpindahan panas untuk steam didapatkan

hi = 3,4991 Btu/jam.ft²°F

hio = hi x (ID/OD)

$$= 4{,}2091168 \text{ Btu/jam ft}^2\ ^o\text{F}$$

E. Menghitung clean overall coefficient (U_C)

$$U_C = \frac{ho \times hio}{ho + hio}$$

$$= \frac{132{,}3 \times 4{,}2091}{132{,}3 + 4{,}2091}$$

$$= 4{,}0793 \quad \text{Btu/jam ft}^2{}^\circ\text{F}$$

F. Menghitung design overall coefficiet (U_D)

$$Rd = \frac{U_C - U_D}{U_C \times U_D}$$

$$\frac{1}{U_D} = \frac{1}{U_C} + Rd$$

$$\frac{1}{U_D} = \frac{1}{4{,}079} + 0{,}0010$$

$$\frac{1}{U_D} = 0{,}2461$$

$$U_D = 4{,}063 \quad \text{Btu/jam ft}^2{}^\circ\text{F}$$

G. Menghitung luas permukaan (A) yang diperlukan

$$A = \frac{Q}{U_D \times \Delta t} = \frac{426506{,}9077}{4{,}0628 \times 180{,}0000} = 583{,}21793 \quad \text{ft}^2$$

$$L = \frac{A}{a''} = \frac{583{,}22}{0{,}4350} = 256{,}32 \quad \text{ft}$$

H. Menghitung dirt factor (Rd) yang terpakai

$$Rd = \frac{U_C - U_D}{U_C \times U_D}$$

$$= \frac{4{,}0793 - 4{,}0628}{4{,}0793 \times 4{,}0628}$$

$$= 0{,}001 \quad \text{jam ft}^2\ {}^\circ\text{F/Btu}$$

I. Mencari panjang ekonomis

dengan mencari over design yang terkecil dari panjang pipa standart

L (ft)	n	n_{pakai}	L_{baru}	A_{baru}	$U_{D\ baru}$	Rd_{baru}	$Rd_{over\ desain}$
12	24	11	256,32	111,50	0,0090	-1000	-250001
17	34	8	256,32	111,50	0,0090	-1000	-250001
20	40	6	256,32	111,50	0,0090	-1000	-250001

Karena over desainnya sama, maka dipilih DPHE dengan jumlah hairpin paling sedikit.

L = 20 ft dan n = 6 buah

Evaluasi Δp

Annulus	Inner
1. Pada NRe_{an} = 395562,0675	1. Pada NRe_p = 17372477,3519
$f = 0{,}0035 + \dfrac{0{,}264}{NRe^{0,42}}$	$f = 0{,}0035 + \dfrac{0{,}264}{NRe^{0,42}}$
$= 0{,}0035 + \dfrac{0{,}264}{224{,}3005}$	$= 0{,}0035 + \dfrac{0{,}264}{1098{,}35}$
$= 0{,}0047$	$= 0{,}0037$
2. ρ = 59,8296 lb/ft^3	2. ρ = 993,622 kg/m^3
$\Delta P_1 = \dfrac{4 . f . G_{an}^2 . L}{2 . g . \rho^2 . do} \times \dfrac{\rho}{144}$	= 62,0020 lb/ft^3
$= 3{,}6968 \times 0{,}4155$	$\Delta P_p = \dfrac{4 . f . G_p^2 . L}{2 . g . \rho^2 . do} \times \dfrac{\rho}{144}$
= 1,5359 Psi	$= 0{,}709 \times 0{,}4306$
	= 0,3055 Psi
3. $V = \dfrac{G_{an}}{3600 \times \rho}$	$\Delta P_p < \Delta P_{allow}$
$= \dfrac{395562{,}0675}{3600 \times 59{,}830}$	$0{,}3055 < 2$
$= 0{,}2624$	Memadai
$\Delta P_n = n \times \left(\dfrac{V^2}{2 . gc}\right) \times \left(\dfrac{\rho}{144}\right)$	
$= 6 \times 0{,}0011 \times 0{,}4155$	
= 0,0028 Psi	
$\Delta P_{an} = \Delta P_1 + \Delta P_n$	
$= 1{,}5359 + 0{,}0028$	
= 1,5388 Psi	
$\Delta P_{an} < \Delta P_{allow}$	
$1{,}5388 < 10$	
Memadai	

Spesifikasi alat :

Nama alat	:	Heater(E-113)						
Fungsi	:	Menaikkan suhu HCHO sebelum masuk ke Reaktor (R-110)						
Tipe	:	Double pipe heat exchanger						
Bahan konstruksi	:	Carbon steel						
Media pemanas	:	Steam						
Kapasitas	:	23414,22152		kg/jam				
Rate steam	:	494,7920		kg/jam				
Ukuran	:	3" × 2" IPS sch. 40						
Dimensi	:	Bagian anulus			Bagian pipa			
		a_{an}	= 2,63	in^2	a_p	=	1,5	in^2
		de	= 2,02	in	di	=	1,4	in
		de'	= 0,81	in	do	=	1,7	in
					a"	=	0,4	ft^2/ft
Jumlah hair pin	:	6	buah					
Jumlah	:	1						

8. Heater (E-116)

Fungsi : Untuk memanaskan NaOH sebelum masuk Reaktor (R-110)

Tipe : Double pipe Heat exchanger

Direncanakan:

- faktor kekotoran gabungan minimum (Rd) = 0,0025 jam. Ft^2 (*kern* , Halaman 107)
- penurunan tekanan aliran maksimum (Δp) = 10 psi
- ΔP maksimum steam = 2 psi
- Digunakan pipa ukuran 1 in
- pipa : Steam
- Anulus : NaOH

Dasar perencanaan:

Dari Appendix B dan C didapatkan data sebagai berikut:

- Masssa bahan masuk (M)	=	23414,222	kg/jam						
	=	51618,993	lb/jam						
	=								
- Suhu bahan masuk (t_1)	=	30	℃	=	86	℉	=	303,15	K
- Suhu bahan keluar (t_2)	=	60	℃	=	140	℉	=	333,2	K
- Kebutuhan steam (m)	=	457,08672	kg/jam						
	=	1007,693	lb/jam						

- Panas yang dibawah steam = 23105,202 kj/jam
  = 21899,503 btu/jam
- steam masuk pada suhu (T_1) = 130 °C = 266 °F
- Steam keluar pada suhu (T_2) = 130 °C = 266 °F
- Beban Panas = 993523,6924 = 394005,271 Btu/jam
- Pipa = Steam
- Anulus = NaOH

Perhitungan

A. Menghitung Δt

$\Delta t_1 = T_1 - t_2 = 266 - 140\ °F = 126\ °F$

$\Delta t_2 = T_2 - t_1 = 266 - 86\ °F = 180\ °F$

$$\Delta T_{LM} = \frac{\Delta t_1 - \Delta t_2}{\ln \Delta t_1 / \Delta t2}$$

$$= \frac{126 - 180}{\ln \frac{126}{180}}$$

$$= 151,3984\ °F$$

B. Menghitung suhu Kalorik (T_c dan t_c)

$Tc = (T_1 + T_2)/2 = 266\ °F = 130\ °C$

$tc = (t1 + t2)/2 = 156\ °F = 69\ °C$

$$= \frac{130 - 69}{\ln \frac{130}{69}}$$

$$= 96,2320\ °F$$

C. Trial U_D

- Asumsi UD = 100,0000 Btu/jam.ft².°F

$$A = \frac{Q}{U_d \cdot \Delta t}$$

$$= \frac{394.005,2714\ \text{Btu/jam}}{100,0000\ \text{Btu/jam.ft}^2.°F \times 96,23\ °F}$$

$$= 40,9433\ \text{ft}^2$$

D Trial ukuran double pipe:

dicoba ukuran double pipe 2 1/2 'x 1 1/4" IPS sec. 40 dengan aliran steam

Bagian pipa anulus (Kern tabel 6.2 ha 110)

a_{an}	=	3	in^2	=	0,0183	ft^2
de	=	2	in	=	0,1683	ft
de'	=	1	in	=	0,0675	ft

Bagian Pipa (Kern, tabel 11 hal 844)

ap	=	2	in^2	=	0,0104	ft^2
di	=	1	in	=	0,1150	ft
do	=	2	in	=	0,1383	ft
a"	=	0	ft^2/ft	=		

Evaluasi Perpindahan Panas	
Annulus, NaOH	*Hot fluida,inner pipe ,steam*
1. Menghitung Nre anulus	1. Menghitung N_{Re} pipa
Gaan = $\frac{m}{a_{an}}$	$G_p = \frac{m}{a_p}$
= $\frac{51618{,}993 \text{ lb/jam}}{0{,}0183 \text{ ft}^2}$	= $\frac{394005{,}2714 \text{ lb/jam}}{0{,}0104 \text{ ft}^2}$
= 2826287,1 lb/jam.ft²	= 37824506,0563 lb/jam ft2
pada tc = 86 °F	μ pada T_c = 266 °F
μ = 1,90 Cp	= 0,993 cp
(fig.24"kern",hal 834)	*(Geankoplis, tabel A.2-4, hal 855)*
$N_{Re} = \frac{G_{AA} \text{ x di}}{\mu \text{ x } 2}$	$NRe_p = \frac{G_p \times di}{\mu \text{ x } 2{,}42}$
= $\frac{2826287{,}1 \text{ x } 0{,}1683}{1{,}9000 \text{ x } 2}$	= $\frac{37824506{,}0563 \text{ x } 0{,}1150}{0{,}9930 \text{ x } 2{,}42}$
= 103470,7092	= 1810116,3502
2. JH = 35 (fig 24" kern" hal 834	2. JH = 24 (fig 24" kern" hal 834
3. Menghitung harga koefisien film	3. Menghitung harga koefisien film
Cp = 0,9989 Btu/lb°F	Cp = 0,234 Btu/lb°F
k = 0,273 Btu/jam.ft²°F/ft	k = 0,122 Btu/jam.ft²°F/ft

$\left(\frac{Cp\ \mu}{k}\right)^{1/3} = \left(\frac{1,00 \times 1,9}{0,2730}\right)^{1/3}$ $= 1,9086$ $ho = \frac{Jh \times K \times}{De} \left(\frac{Cp.\mu}{k}\right)^{1/3}$ $= 108,3340278$ $\frac{ho}{\varphi s} = 397$ u/jam ft^2	3. Harga koefisien perpindahan panas untuk steam didapatkan hi = 1,439 Btu/jam.ft²°F hio = hi x (ID/OD) = 1,7309402 Btu/jam ft^2 °F

E. Menghitung clean overall coefficient (U_C)

$$U_C = \frac{ho \times hio}{ho + hio}$$

$$= \frac{108,3 \times 1,7309}{108,3 + 1,7309}$$

$$= 1,7037 \text{ Btu/jam ft}^2 °F$$

F. Menghitung design overall coefficiet (U_D)

$$Rd = \frac{U_C - U_D}{U_C \times U_D}$$

$$\frac{1}{U_D} = \frac{1}{U_C} + Rd$$

$$\frac{1}{U_D} = \frac{1}{1,704} + 0,0010$$

$$\frac{1}{U_D} = 0,5880$$

$$U_D = 1,701 \text{ Btu/jam ft}^2 °F$$

G. Menghitung luas permukaan (A) yang diperlukan

$$A = \frac{Q}{U_D \times \Delta t} = \frac{394005,2714}{1,7008 \times 180,0000} = 1286,9776 \text{ ft}^2$$

$$L = \frac{A}{a''} = \frac{1286,98}{0,4350} = 256,32 \text{ ft}$$

H. Menghitung dirt factor (Rd) yang terpakai

$$Rd = \frac{U_C - U_D}{U_C \times U_D}$$

$$= \frac{1{,}7037 - 1{,}7008}{1{,}7037 \times 1{,}7008}$$

$$= 0{,}001 \text{ jam ft}^2\ °F/Btu$$

I. Mencari panjang ekonomis

dengan mencari over design yang terkecil dari panjang pipa standart

L (ft)	n	n_{pakai}	L_{baru}	A_{baru}	$U_{D\ baru}$	Rd_{baru}	$Rd_{over\ desain}$
12	24	11	256,32	111,50	0,0090	-1000	-250001
17	34	8	256,32	111,50	0,0090	-1000	-250001
20	40	6	256,32	111,50	0,0090	-1000	-250001

hairpin

paling sedikit.

L = 20 ft dan n = 6 buah

Evaluasi Δp

Annulus

1. Pada NRe_{an} = 103470,7092

$$f = 0{,}0035 + \frac{0{,}264}{NRe^{0,42}}$$

$$= 0{,}0035 + \frac{0{,}264}{127{,}7095}$$

$$= 0{,}0056$$

2. ρ = 65,2412 lb/ft^3

$$\Delta P_1 = \frac{4 . f . G_{an}^2 . L}{2 . g . \rho^2 . do} \times \frac{\rho}{144}$$

$$= 6{,}3019 \times 0{,}4531$$

$$= 2{,}8552 \text{ Psi}$$

3. $$V = \frac{G_{an}}{3600 \times \rho}$$

$$= \frac{103470{,}7092}{3600 \times 65{,}241}$$

$$= 0{,}0629$$

Inner

1. Pada NRe_p = 1810116,3502

$$f = 0{,}0035 + \frac{0{,}264}{NRe^{0,42}}$$

$$= 0{,}0035 + \frac{0{,}264}{424{,}85}$$

$$= 0{,}0041$$

2. ρ = 993,622 kg/m^3

= 62,0020 lb/ft^3

$$\Delta P_p = \frac{4 . f . G_p^2 . L}{2 . g . \rho^2 . do} \times \frac{\rho}{144}$$

$$= 0{,}667 \times 0{,}4306$$

$$= 0{,}2872 \text{ Psi}$$

$\Delta P_p < \Delta P_{allow}$

0,2872 < 2

Memadai

$\Delta P_n = n \times \left(\frac{V^2}{2 \cdot gc}\right) \times \left(\frac{\rho}{144}\right)$ $= 6 \times 6E\text{-}05 \times 0{,}4531$ $= 0{,}0002$ Psi $\Delta P_{an} = \Delta P_1 + \Delta P_n$ $= 2{,}8552 + 0{,}0002$ $= 2{,}8553$ Psi $\Delta P_{an} < \Delta P_{allow}$ $2{,}8553 < 10$ Memadai	

Spesifikasi alat :

Nama alat	:	Heater(E-116)					
Fungsi	:	Menaikkan suhu NaOH sebelum masuk ke Reaktor (R-110)					
Tipe	:	Double pipe heat exchanger					
Bahan konstruksi	:	Carbon steel					
Media pemanas	:	Steam					
Kapasitas	:	23414,22152 kg/jam					
Rate steam	:	457,0867 kg/jam					
Ukuran	:	3" × 2" IPS sch. 40					
Dimensi	:	Bagian anulus			Bagian pipa		
		a_{an}	= 3	in^2	a_p	= 1,5	in^2
		de	= 2	in	di	= 1,4	in
		de'	= 1	in	do	= 1,7	in
					a"	= 0,4	ft^2/ft
Jumlah hair pin	:	6 buah					
Jumlah	:	1					

9. Heater (E-119)

Fungsi : Untuk memanaskan C_2H_4O sebelum masuk Reaktor (R-110)

Tipe : Double pipe Heat exchanger

Direncanakan:

- faktor kekotoran gabungan minimum (Rd) = 0,0025 jam. Ft² (*kern* , Halaman 107)
- penurunan tekanan aliran maksimum (Δp) = 10 psi
- ΔP maksimum steam = 2 psi

- Digunakan pipa ukuran 1 in
- pipa : Steam
- Anulus : C_2H_4O

Dasar perencanaan:

Dari Appendix B dan C didapatkan data sebagai berikut:

- Masssa bahan masuk (M)	=	23414,222	kg/jam					
	=	51618,993	lb/jam					
	=							
- Suhu bahan masuk (t_1)	=	30	°C	=	86	°F	=	303,15 K
- Suhu bahan keluar (t_2)	=	60	°C	=	140	°F	=	333,2 K
- Kebutuhan steam (m)	=	491,84121	kg/jam					
	=	1084,313	lb/jam					
- Panas yang dibawah steam	=	24862,001	kj/jam					
	=	23564,627	btu/jam					
- steam masuk pada suhu (T_1)	=	130	°C	=	266	°F		
- Steam keluar pada suhu (T_2)	=	130	°C	=	266	°F		
- Beban Panas	=	1069066,0441		=	423963,374	Btu/jam		

- Pipa = Steam
- Anulus = C_2H_4O

Perhitungan

A. Menghitung Δt

$\Delta t_1 = T_1 - t_2 = 266 - 140\ °F = 126\ °F$

$\Delta t_2 = T_2 - t_1 = 266 - 86\ °F = 180\ °F$

$$\Delta T_{LM} = \frac{\Delta t_1 - \Delta t_2}{\ln \Delta t_1 / \Delta t2}$$

$$= \frac{126 - 180}{\ln \frac{126}{180}}$$

$$= 151,3984\ °F$$

B. Menghitung suhu Kalorik (T_c dan $t_{c)}$

$Tc = (T_1 + T_2)/2 = 266\ °F = 130\ °C$

$tc = (t1 + t2)/2 = 156\ °F = 69\ °C$

$$= \frac{130 - 69}{\ln \frac{130}{69}}$$

= 96,2320 °F

C. Trial U_D

- Asumsi UD = 100,0000 Btu/jam.ft².°F

$$A = \frac{Q}{U_d \cdot \Delta t}$$

$$= \frac{423.963,3741 \text{ Btu/jam}}{100,0000 \text{ Btu/jam.ft}^2.°F \times 96,23 °F}$$

= 44,0564 ft²

D Trial ukuran double pipe:

dicoba ukuran double pipe 2 1/2 'x 1 1/4" IPS sec. 40 dengan aliran steam

Bagian pipa anulus (Kern tabel 6.2 ha 110)

a_{an}	=	3	in^2	=	0,0183	ft^2
de	=	2	in	=	0,1683	ft
de'	=	1	in	=	0,0675	ft

Bagian Pipa (Kern, tabel 11 hal 844)

ap	=	2	in^2	=	0,0104	ft^2
di	=	1	in	=	0,1150	ft
do	=	2	in	=	0,1383	ft
a"	=	0,435	ft^2/ft	=		

Evaluasi Perpindahan Panas	
Annulus, C_2H_4O	*Hot fluida,inner pipe ,steam*
1. Menghitung Nre anulus Gaan = $\frac{m}{a_{an}}$ = $\frac{51618,993 \text{ lb/jam}}{0,0183 \text{ ft}^2}$ = 2826287,1 lb/jam.ft² pada tc = 86 °F μ = 1,9 Cp (fig.24"kern",hal 834)	1. Menghitung N_{Re} pipa G_p = $\frac{m}{a_p}$ = $\frac{423963,3741 \text{ lb/jam}}{0,0104 \text{ ft}^2}$ = 40700483,9122 lb/jam ft2 μ pada T_c = 266 °F = 0,98 cp *(Geankoplis, tabel A.2-4, hal 855)*

$N_{Re} = \dfrac{G_{AA} \times di}{\mu \times 2{,}42}$

$= \dfrac{2826287{,}1 \times 0{,}1683}{1{,}9000 \times 2{,}42}$

$= 103470{,}7092$

2. JH = 46 (fig 24" kern" hal 834
3. Menghitung harga koefisien film

Cp = 0,143 Btu/lb°F

k = 0,273 Btu/jam.ft²°F/ft

$\left(\dfrac{Cp\ \mu}{k}\right)^{1/3} = \left(\dfrac{0{,}14 \times 1{,}9}{0{,}2730}\right)^{1/3}$

$= 0{,}9984$

$ho = \dfrac{Jh \times K}{De} \times \left(\dfrac{Cp.\mu}{k}\right)^{1/3}$

$= 74{,}4833759$

$\dfrac{ho}{\varphi s} = 273$ Btu/jam ft^2 ^oF

$NRe_p = \dfrac{G_p \times di}{\mu \times 2{,}42}$

$= \dfrac{40700483{,}9122 \quad 0{,}1150}{0{,}9800 \times 2{,}42}$

$= 1973585{,}6173$

2. JH = 34 (fig 24" kern" hal 834
3. Menghitung harga koefisien film

Cp = 0,234 Btu/lb°F

k = 0,122 Btu/jam.ft²°F/ft

3. Harga koefisien perpindahan panas untuk steam didapatkan

hi = 2,0385 Btu/jam.ft²°F

hio = hi x (ID/OD)

= 2,4521652 Btu/jam ft^2 ^oF

E. Menghitung clean overall coefficient (U_C)

$U_C = \dfrac{ho \times hio}{ho + hio}$

$= \dfrac{74{,}5 \times 2{,}4522}{74{,}5 + 2{,}4522}$

$= 2{,}3740$ Btu/jam ft^2°F

F. Menghitung design overall coefficiet (U_D)

$Rd = \dfrac{U_C - U_D}{U_C \times U_D}$

$\dfrac{1}{U_D} = \dfrac{1}{U_C} + Rd$

$\dfrac{1}{U_D} = \dfrac{1}{2{,}374} + 0{,}0010$

$\dfrac{1}{U_D} = 0{,}4222$

U_D = 2,368 Btu/jam ft^2°F

G. Menghitung luas permukaan (A) yang diperlukan

$$A = \frac{Q}{U_D \times \Delta t} = \frac{423963,3741}{2,3684 \times 180,0000} = 994,49719 \text{ ft}^2$$

$$L = \frac{A}{a''} = \frac{994,50}{0,4350} = 256,32 \text{ ft}$$

H. Menghitung dirt factor (Rd) yang terpakai

$$Rd = \frac{U_C - U_D}{U_C \times U_D}$$

$$= \frac{2,3740 - 2,3684}{2,3740 \times 2,3684}$$

= 0,001 jam ft^2 °F/Btu

I. Mencari panjang ekonomis

dengan mencari over design yang terkecil dari panjang pipa standart

L (ft)	n	n_{pakai}	L_{baru}	A_{baru}	$U_{D\ baru}$	Rd_{baru}	$Rd_{over\ desain}$
12	24	11	256,32	111,50	0,0090	-1000	-250001
17	34	8	256,32	111,50	0,0090	-1000	-250001
20	40	6	256,32	111,50	0,0090	-1000	-250001

Karena over desainnya sama, maka dipilih DPHE dengan jumlah hairpin paling sedikit.

L = 20 ft dan n = 6 buah

Evaluasi Δp	
Annulus	**Inner**
1. Pada NRe_{an} = 103470,7092	1. Pada NRe_p = 1973585,6173
$f = 0,0035 + \frac{0,264}{NRe^{0,42}}$	$f = 0,0035 + \frac{0,264}{NRe^{0,42}}$
$= 0,0035 + \frac{0,264}{127,7095}$	$= 0,0035 + \frac{0,264}{440,56}$
= 0,0056	= 0,0041
2. ρ = 78,2342 lb/ft^3	2. ρ = 993,622 kg/m^3
$\Delta P_1 = \frac{. G_{an}^2 . L}{2 . g . \rho^2 . do} \times \frac{\rho}{144}$	= 62,0020 lb/ft^3
= 4,3825 × 0,5433	$\Delta P_p = \frac{. G_p^2 . L}{2 . g . \rho^2 . do} \times \frac{\rho}{144}$

$= 2{,}3810$ Psi	$= 0{,}768 \times 0{,}4306$
	$= 0{,}3308$ Psi
3. $V = \dfrac{G_{an}}{3600 \times \rho}$	$\Delta P_p < \Delta P_{allow}$
$= \dfrac{103470{,}7092}{3600 \times 78{,}234}$	$0{,}3308 < 2$
$= 0{,}0525$	Memadai
$\Delta P_n = n \times \left(\dfrac{V^2}{2 \cdot gc}\right) \times \left(\dfrac{\rho}{144}\right)$	
$= 6 \times 4E\text{-}05 \times 0{,}5433$	
$= 0{,}0001$ Psi	
$\Delta P_{an} = \Delta P_1 + \Delta P_n$	
$= 2{,}3810 + 0{,}0001$	
$= 2{,}3811$ Psi	
$\Delta P_{an} < \Delta P_{allow}$	
$2{,}3811 < 10$	
Memadai	

Spesifikasi alat :

Nama alat	:	Heater(E-119)
Fungsi	:	Menaikkan suhu C_2H_4O sebelum masuk ke Reaktor (R-110)
Tipe	:	Double pipe heat exchanger
Bahan konstruksi	:	Carbon steel
Media pemanas	:	Steam
Kapasitas	:	23414,22152 kg/jam
Rate steam	:	491,8412 kg/jam
Ukuran	:	3" × 2" IPS sch. 40
Dimensi	:	Bagian anulus / Bagian pipa

Bagian anulus				Bagian pipa			
a_{an}	=	3	in^2	a_p	=	1,5	in^2
de	=	2	in	di	=	1,4	in
de'	=	1	in	do	=	1,7	in
				a''	=	0,4	ft^2/ft

Jumlah hair pin	:	6	buah
Jumlah	:	1	

10. Netralizer (R-120)

Fungsi : Untuk menetralkan larutan saat kelebihan alkali

Jumlah : 1 unit

Tipe : dasar dan tutup tangki berbentuk ellipsoidal dilengkapi dengan koil pendingin dan mesin pengaduk

Bahan : *Carbon Steel SA-285*

Kondisi reaksi : T = 60 ^{0}C, P = 1 atm

Laju alir massa, G = 30.280,6021 Kg/jam

= 66.756,6153 lb/jam

Densitas campuran, ρ = 973,9990 Kg/m³

= 60,8070 lb/ft³

Fluida Dingin : Umpan Netralizer

W_1 = 30.280,6021 Kg/jam = 66.757,2209 lb/jam

T_1 = 60,00 °C = 140,00 °F

T_2 = 60,00 °C = 140,00 °F

Fluida Panas : Steam

W_2 = 67.329,5792 Kg/jam = 148.436,1368 lb/jam

t_1 = 130,00 °C = 266,00 °F

t_2 = 125,00 °C = 257,00 °F

Perhitungan design sesuai dengan literatur pada *Kern*

1. Beban Panas

Q = 146.347.573,2541 kcal/jam = 580.754.148,2435 Btu/jam

2. LMTD

Fluida Panas		Fluida Dingin	Selisih
266,00 °F	Suhu tinggi	140,00 °F	Δt_1 : 126,00 °F
257,00 °F	Suhu rendah	140,00 °F	Δt_2 : 117,00 °F
9,00 °F	ΔT Selisih Δt	0,00 °F	9,00 °F

$$\text{LMTD} = \frac{\Delta t_2 - \Delta t_1}{\ln(\Delta t_2 - \Delta t_1)}$$

$$= \frac{126{,}00\ °F - 117{,}00\ °F}{\ln(126{,}00\ °F - 117{,}00\ °F)}$$

$$= 4{,}10\ °F$$

Dari tabel 8 (*Kern*, 1959), diperoleh harga U_D = 500 - 3000 Btu/ft^2 jam ^{o}F.

a. Trial U_D

- Asumsi UD = 2.500,0000 Btu/jam.ft².°F *(Tabel 8, Kern)*

$A_c = \dfrac{Q}{U_d \cdot \Delta t}$

$= \dfrac{580.754.148{,}2435 \text{ Btu/jam}}{2.500{,}0000 \text{ Btu/jam.ft}^2.°F \times 4{,}10\ °F}$

$= 56.713{,}2128 \text{ ft}^2 \times \dfrac{1{,}0000 \text{ m}^2}{10{,}7638 \text{ ft}^2}$

$= 5.268{,}8617 \text{ m}^2$

Dipilih pipa dengan ukuran 0,75 inch *schedule* 40 untuk pipa koil di dalam reaktor.

Dari tabel 11 (*kern* 1959) diperoleh ukuran pipa sebagai berikut :

OD	= 0,7500 in	= 0,0625 ft	= 0,0191 m
BWG	= 16		
ID	= 0,6200 in	= 0,0517 ft	= 0,0157 m
a't	= 0,3020 in²	= 0,0021 ft²	= 0,0002 m²
a"	= 0,1963 ft²/lin.ft		

Luas permukaan koil, A_c = a" . L

$L = \dfrac{56.713{,}2128 \text{ ft}^2}{0{,}1963 \text{ ft}^2/\text{lin.ft}}$

$= 288.910{,}9159 \text{ ft} \times \dfrac{1{,}0000 \text{ m}}{3{,}2808 \text{ ft}}$

$= 88.060{,}3128 \text{ m}$

Volume koil, $V_k = \dfrac{\pi \cdot OD_{pipa}^{\,2} \cdot L}{4}$

$= \dfrac{3{,}1429 \times (0{,}0191 \text{ m})^2 \times 88.060{,}3128 \text{ m}}{4}$

$= 25{,}1093 \text{ m}^3$

Tangki di disain dengan faktor keamanan 20%

Voluem tangki, V_t = (1 + 20%) x V_k)

= (1 + 20%) x 25,1093 m³)

= 30,1312 m³

Perbandingan antara tinggi tangki dengan tinggi Ellipsoidal terhadap diameter ialah :

$H_s : D_t = 1{,}5 : 1$

$h_s : D_t = 1 : 6$

$D_c : D_t = 8 : 10$

Volume tangki

V_t = $V_{slinder} + 2.V_{Ellipsoidal}$

$V_t = \frac{\pi \,.\, D^2 .\, H}{4} + 2 \,.\, \frac{\pi \,.D^2 .\, h}{6}$

$= \frac{3,14 \,.\quad 1\,1/2 \,.\, D^3}{4} + 2 \,.\, \frac{3,14 \quad 1/6 \,.\, D^3}{6}$

$30,1312\ m^3 = 1,1786\ D^3 + 0,1746\ D^3$

$D^3 = \frac{30,1312\ m^3}{1,1786 + 0,1746}$

$D^3 = 22,2670\ m^3$

$D = \sqrt[3]{22,2670\ m^3}$

$= 2,8133\ m \times 3,2808\ ft/m$

$= 9,2301\ ft$

$= 2,8133\ m \times 39,3700\ in/m$

$= 110,7607\ in$

Tinggi tangki ;

Tinggi slinder, H_s = 1 1/2 . D

= 1 1/2 x 2,8133 m

= 4,2200 m x 3,2808 ft/m

= 13,8451 ft

Tinggi ellipsoidal, h_s = 1/6 . D

= 1/6 x 2,8133 m

= 0,4689 m x 3,2808 ft/m

= 1,5383 ft

Tinggi tangki, H_t = $H_s + 2.h_s$

= 4,2200 m + (2 x 0,4689 m)

= 5,1578 m x 3,2808 ft/m

= 16,9218 ft

Tinggi penyangga, H_p = 1,0000 m

Tinggi tangki total, H_{tot} = $H_t + H_p$

= 5,1578 m + (1,0000 m)

= 6,1578 m

Diameter spiral, D_c = 4/5 . D

= 4/5 x 2,8133 m

= 2,2507 m x 3,2808 ft/m

= 7,3840 ft

Panjang koil/lilitan = π . Dc

= 3,1429 x 2,2507 m

= 7,0735 m /lilitan

Jumlah llilitan koil, L_k = $\frac{\text{Panjang koil total } (L_k)}{\text{Panjang koil/lilitan (L)}}$

= $\frac{88.060,3128 \text{ m}}{7,0735 \text{ m /lilitan}}$

= 12.449,2976 lilitan = 155 lilitan

Jarak antara lilitan = $\frac{H_s - (L \times OD_{koil})}{L - 1}$

= $\frac{4,2200 \text{ m} - (155 \text{ lilitan} \times 0,0191 \text{ m})}{155 \text{ lilitan} - 1}$

= 0,0082 m

Volume ellipsoidal,V_e = $\frac{\pi . D^2 . h}{6}$

= $\frac{3,1429 \times (2,8133 \text{ m})^2 \times 0,4689 \text{ m}}{6}$

= 1,9439 m³

Tinggi cairan, H_c = $\frac{(V_k - V_{e\ bottom}) \times 4}{3,14 \times D^2} + h_s$

= $\frac{(28,1872 \text{ m}^3) \times 4}{3,1429 \times (2,8133 \text{ m})^2}$ + 0,4689 m

= 5,0015 m x 3,2808 ft/m

= 16,4090 ft

Tekanan hidrostatis, P_h = ρ x g x H_c

= 973,9990 Kg/m³ x 9,8000 m/s² 5,0015 m

= 47.740,0431 N/m² x $\frac{14,6960 \text{ Psi}}{1,01325 \times 10^5 \text{ N/m}^2}$

= 6,9241 Psi

Tekanan sistem, P_s = 1,0000 atm x 14,6960 Psi/atm
= 14,6960 Psi
Faktor keamanan = 20%
Tekanan total desain, P_t = (Ph + Ps) x (1 + 0,2)
= (6,9241 Psi + 14,6960 Psi) x (1 + 0,2)
= 25,9441 Psi

Diameter tangki, Dt = 110,7607 in
Max Allowable Stress , F = 13.800,0000 Psi
Effisiensi sambungan, E = 0,85
Faktor korosi, C = 0,0060 in
Umur alat, n = 20 tahun
Tebal plate dinding tangki, t_s

$$t = \frac{P \times 0{,}5\ D}{F.E - 0{,}6\ P}$$

$$= \frac{25{,}9441\ Psi \times 0{,}5 \times 110{,}7607\ in}{(13.800\ Psi \times 0{,}85) - (0{,}6 \times 25{,}9441\ Psi)} + (0{,}006\ in \times 20\ tahun)$$

= 0,2427 in x 2,5400 cm/in
= 0,6163 cm
maka diperoleh OD
= Dt + 2t
= 111,2460 in x 0,0254 m/in
= 2,8256 m

Tebal plate tutup tangki, t_E

$$t = \frac{P \times D_t}{2\{(F.E) - (0{,}2\ P)\}} + c.n$$ *(Timmerhaus, 1991, hal. 537)*

$$= \frac{25{,}9441\ Psi \times 110{,}7607\ in}{2[(13.800\ Psi \times 0{,}85) - (0{,}2 \times 25{,}9441\ Psi)]} + 0{,}0060\ in \times 20\ tahun$$

= 0,1225 in x 2,5400 cm/in
= 0,3113 cm

Sebagai konstruksi dipilih baja anti karat SA – 285 C dengan ketebalan plat 0,2427 inci. Tangki dilengkapi dengan pengaduk *Marine propeller* tiga daun, dari (*McCabe* , 1994) diperoleh harga-harga perbandingan untuk tangki sebagai berikut:

D_t / D_i = 3 *(McCabe, 1994, Hal.235)*
w / D_i = 1/5 *(McCabe, 1994, Hal.235)*
Z_i / D_i = 1/3 *(McCabe, 1994, Hal.235)*

Pada harga Dt = 2,8133 m maka diperoleh :
Diameter pengaduk, Di = Dt / 3

$$= \frac{2{,}8133 \text{ m}}{3}$$

= 0,9378 m x 3,2808 ft/m = 3,0767 ft

lebar daun impeler, w = 1/5 x Di
= 1/5 x 0,9378 m
= 0,1876 m x 3,2808 ft/m = 0,6153 ft

Tinggi pengaduk, Zi = 1/3 x Di
= 1/3 x 0,9378 m
= 0,3126 m x 3,2808 ft/m = 1,0256 ft

Maka besarnya pemakaian daya untuk pengaduk adalah :

$$\text{Daya Pengaduk} = \frac{(N_p).(\rho).(n^3).(D_i^5)}{gc}$$ *(Mc Cabe, 1999)*

$$= \frac{(6{,}2) \quad (60{,}8070 \text{ lb/ft}^3) \quad (0{,}5 \text{ rps})^3 \quad (\quad 3{,}0767 \text{ ft} \;)^5}{32{,}1700 \text{ lb/det}^2}$$

= 403,8319 ft/lbf.det
= 0,7342 Hp

Dimana :
Jumlah putaran pengaduk, n = 30 rpm
= 0,5 rps
Densitas campuran, ρ = 0,0000 lb/ft³
Konstanta pengadukan, Np = 6,2
Efisiensi motor = 70% , maka daya motor

$$P \text{ motor} = \frac{\text{Daya Pengaduk}}{\text{Effisiensi motor}}$$

$$= \frac{0{,}7342 \text{ Hp}}{70\%}$$

= 1,0489 Hp

Spesifikasi Tangki Netralizer :

Daya motor pengaduk = 1,0489 Hp
Diameter tangki, D_t = 2,8133 m
Tinggi tangki total, Htot = 6,1578 m

Kapasitas tangki, V_t = 30,1312 m³/jam
Bahan kontruksi = *Carbon steel SA-285*

11. Pompa Sentrifugal (L-121)

Fungsi = Untuk mengalirkan keluaran reaktor ke netralizer
Tipe = Centrifugal pump
Direncanakan =
Bahan konstruksi: = Comercial Steel
Jumlah = 1 buah

Dasar Perhitungan:
Suhu (T) = 30 °C = 303,150 K
Tekanan (P) = 1 atm
Rate liquid = 70242,6646 kg/jam
= 154857,0 lb/jam
viscositas = 1,9 cP = 0,0012701 lb/ft.s
Perhitungam:
Menghitung Rate Volumetrik (Q)

$$Q = \frac{\text{Rate bahan masuk}}{\rho \text{ bahan masuk}}$$

$$= \frac{154856{,}9783}{60{,}8070}$$

= 2546,6959 ft³/jam
= 0,6876 ft³/s
= 308,6190 gpm

$$Di_{optimum} = 3{,}9 \; Q^{0{,}45} \; x \; \rho^{0.13}$$ *(Pers 15 "Petters & Timmerhaus" hal 496)*

$$= 3{,}9 \; x \; [\; 0{,}6876 \;]^{0{,}45} \; x \; [\; 60{,}8070 \;]^{0{,}13}$$

= 5,6206 in
= 0,4684 ft

Untuk pipa ukuran 4 in sch 80
Sehingga: *Geankoplis* , tabel A.5.1 , hal 892 didapatkan:

OD	=	4,5000	in	=	0,3750	ft
ID	=	3,8250	in	=	0,3188	ft
A	=	0,0798	ft²			

c. Menentukan Kecepatan Aliran Fluida (v)

Kecepatan aliran fluida (v) = Q

$$= \frac{2546{,}7}{0{,}0798}$$ (A)

= 31901,5691 ft/jam

= 8,61342 ft/s

- Menentukan Bilangan Reynold (N_{Re}) = $\frac{D \times v \times \rho}{\mu}$

$$= \frac{0{,}3188 \times 8{,}6134 \times 60{,}8070}{0{,}0013}$$

= 131446,4 ≥ 2100 (aliran turbulen)

Dari *Geankoplis, fig. 2.10 Hal 88* didapatkan

Equivalent rougness (ε) = 0,00005

Relative roungness $\left[\frac{\varepsilon}{D}\right]$ = 0,0001 *(Geankoplis, Tabel 2-10.1 Hal 94)*

Faktor friksi (f) = $\frac{16}{N_{Re}}$ = 0,00012 *(Geankoplis, Tabel 2-10.1 Hal 94)*

- Menentukan Panjang pipa

Asumsi:

Panjang pipa lurus = 75 ft

elbow 90° = 4 buah

Globe valve = 1 buah

Tee = 1 buah

Perhitungan:

- Panjang pipa lurus = 75 ft
- elbow 90° = 4 buah

Le/D = 75

Le = 35 ID (*Geankoplis, Tabel 2-10.1 Hal 93*)

= 35 x 0,3188 x 4 ft

= 44,6250 ft

= 1 buah

- Globe valve = 1 buah

Le/D = 13 (*Geankoplis, Tabel 2-10.1 Hal 93*)

Le = 13 ID

= 13 x 0,3188 x 1 ft

= 4,1438 ft

- Tee = 1 buah

  Le/D = 50 ID *(Geankoplis, Tabel 2-10.1 Hal 93)*

  Le = 50 x 0,3188 x 1 ft

  = 15,9375 ft

Panjang pipa total (L) = Pipa lurus + elbow 90° + globe valve + tee

= 75 + 44,6250 + 4,1438 + 15,9375

= 139,7063 ft

- Menentukan friksion Loss

1. Friksi pada pipa lurus

$$F_f = 4_f \frac{\Delta L}{D} \times \frac{V^2}{2g_c}$$ *(Geankoplis, Persamaan 2.10-6 Hal 86)*

$$= 4 \times 0{,}0030 \times \frac{75}{0{,}3188} \times \frac{(8{,}6134)^2}{2 \times 32{,}174}$$

$$= 4 \times 0{,}0030 \times 235{,}29 \times \frac{1931{,}1982}{64{,}348}$$

= 84,739151 lbf.ft/lbm

2. Sudden Contraction

Karena tangki sangat besar maka A_1 = 0

$$hc = 0{,}55 \times [1 - 0] \times \frac{(8{,}6134)^2}{2 \times 1 \times 32{,}172}$$

$$= 0{,}55 \times [1 - 0] \times \frac{(8{,}6134)^2}{2 \times 1 \times 32{,}172}$$

$$= 0{,}55 \times 1 \times \frac{1931{,}1982}{64{,}3440}$$

= 16,507507 lbl.ft/lbm

3. Sudden Expansion

$$h_{ex} = \left[1 - \frac{A2}{A1}\right] \times \frac{v_2^2}{2 \times \alpha \times gc}$$ (*Geankoplis, Persamaan 2.10-15 Hal 93*)

$$= [1 - 0] \times \frac{(8{,}6134)^2}{2 \times 1 \times 32{,}172}$$

$$= 1 \times \underline{1931{,}1982}$$

$$= 1 \times \frac{1931{,}1982}{64{,}3440}$$

$= 30,0136$ lbf.ft/lbm

4. Elbow 90°, 4 buah

Kf = 0,75 (*Geankoplis, Tabel 2.10.1 Hal 93*)

hf = $1Kf \dfrac{v_2}{2gc}$ (*Geankoplis, Pers 2.10.1 Hal 94*)

$= 1 \times 0,75 \dfrac{(8,6134)^2}{2 \times 32,172}$

$= 1 \times 0,75 \times \dfrac{1931,1982}{64,344}$

$= 22,5102$ lbf.ft/lbm

5. Tee, 1 buah

Kf = 1

hf = $1 Kf \dfrac{v_2}{2gc}$

$= 1 \times 1 \dfrac{(8,6134)^2}{2 \times 32,172}$

$= 1 \times \dfrac{74,1911}{64,3440}$

$= 1,1530378$ lbf.ft/lbm

Total fraksi (∑F) = $F_f + h_c + h_{ex} + h_f$ elbow 90° + hf globe valve

Total fraksi (∑F) = 84,739151 + 16,5075 + 30,0136 + 22,5102 + 1,1530378

= 154,9236 lbf.ft/lbm

e. Menentukan daya pompa

Direncanakan:

ΔZ = 30 ft

ΔP = 30 lb/ft^2

v_1 = 0 ft/detik (karena P_1=P_2)

v_2 = 8,61342 ft/detik (karena fluida diam)

$\dfrac{\varepsilon}{D}$ = 0,0001

Hukum Bernouli

$$\frac{\Delta P}{\rho} + \Delta Z \left[\frac{g}{gc} \right] + \frac{v_2^2}{2 \times \alpha \times gc} + (\sum F) = - Ws$$

$$0 + 30 (1) + \frac{(8,6134)^2}{} + 154,9236 = - Ws$$

$$-Ws = 30 + \frac{2 \times 1 \times 32,172}{64,3440} \; 74,1911 + 154,9236 =$$

$-Ws = 186,07662$ lbf.ft/lbm

Dengan: Capacity = 308,6190 gal/menit

Dari Fig 14.36, Hal. 520, Petters & Timmerhause, didapatkan:

Efisiensi pompa (η) = 40%

$-Ws = -\eta \; Wp$

$186,0766 = -40\% \; Wp$

$Wp = 465,19154$ ft.lb/lbm

mass flow rate (m) = Q x ρ

= 0,6876 x 60,8070

= 41,8114 lbm/s

$$WHp = Wp \times m \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

$$WHp = 465,19154 \times 41,8114 \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

$WHp = 35,3642$ hp

$$BHp = \frac{WHp}{\eta}$$

$$= \frac{35,3642}{40\%}$$

= 88,4105 Hp = 88 Hp

Dari Fig 14.38 Hal. 521, Petters & Timmerhause, didapatkan:

Spesifikasi Pompa Sentrifugal = 89%

$$= \frac{\text{Pump horsepower}}{\text{Efisiensi motor}}$$

$$= \frac{88,4105}{89\%}$$

= 99,3376 Hp ≈ 99,3 Hp

Spesifikai Pompa Sentrifugal

Fungsi	:	Untuk mengalirkan keluaran netralizer ke evaporator
Kode alat	:	L-121
Tipe	:	Centrifugal pump
kapasitaas	:	308,6190 gpm

Suhu Operasi		:	303,150 K				
Tekanan Operasi		:	1 atm				
Efisiensi Pompa		:	89%				
ΔP		:	30 lb/ft²				
Dimensi	NPS	:	4 in	OD :	4,5000	A :	0,0798
	Sch	:	80	ID :	3,8250		

12. Storage CH_2O_2 (F-122)

Fungsi : Menyimpan CH_2O_2 selama 7 hari

Tipe : Bejana tegak dengan tutup atas standart dishes dan tutup bawah flat (datar)

Direncanakan :

Suhu	:	30	˚C	=	303,15	K
Tekanan Operasi	:	1	atm	=	14,7	psia
Rate masuk	:	10691,8880	kg/jam	=	23571,33619	lb/jam
				=	565712,0687	lb/hari
Densitas	:	1,343	gr/cm^3	=	83,8408	lb/ft^3
Waktu tinggal	:	7	hari	=	168	jam
Bahan konstruksi	:	Stainless steel SA 240 Grade M Type 316				
Pengelasan	:	Double welded butt joint E		=	0,8	
Faktor korosi	:	1/16	in			
Allowable stress	:	18750				
Volume kosong	:	20%	volume total			
Jumlah Tangki	:	1	buah			

Perhitungan :

a. Menentukan Volume

Volume bahan baku : $\frac{m}{\rho}$ x waktu tinggal

: $\frac{23571,3362}{83,8408}$ x 168 jam

: 47232,2162 ft^3

volume liquid : $\frac{47232,2162}{1}$ = 47232,2162 ft^3

V_T : V_L + V_{RK}

: 47232,2162 + 0,2 V_T

: 59040,2703 ft^3

b. Menentukan Diameter

Diketahui : $Ls = 1,5 \; di$

$V_{tangki} = V_{silinder} + V_{tutup\ atas\ SD}$

$59040,2703 = \left(\frac{\pi}{4} \times di^2 \times Ls\right) + 0,0847 \; di^3$

$59040,2703 = 1,1775 \; di^3 + 0,0847 \; di^3$

$59040,2703 = 1,2622 \; di^3$

$di^3 = 46775,6855$

$di = 36,0308 \; ft$

$= 432,3691 \; in$

c. Menentukan tinggi tangki yang terisi bahan

$V_{tangki} = V_{silinder} + V_{tutup\ atas\ SD}$

$47232,2162 = \left(\frac{\pi}{4} \times di^2 \times Lls\right) + 0,0847 \; di^3$

$47232,2162 = \left(\frac{\pi}{4} \times 36,0308^2 \times Lls\right) + 0,0847 \times 36,0308$

$47232,2162 = 1019,0991 \; Lls + 3961,901$

$43270,3156 = 1019,0991 \; Lls$

$Lls = 42,4594 \; ft$

$= 509,5125 \; in$

$Ls = 1,5 \times di$

$= 1,5 \times 432,3691$

$= 648,5536 \; in$

$= 54,0461 \; ft$

d. Menghitung tebal silinder

$P_{hidrostatik} = \frac{\rho (H-1)}{144}$ (Brownell dan Young pers. 3.17 Hal 46)

$= \frac{83,8408 \times (54,0461 - 1)}{144}$

$= 30,8849 \; psia$

$Pi = P_{atm} + P_{hidrostatik}$

$= 14,6959 + 30,8849$

$= 45,5808 \; psia$

$= 30{,}8808$ psig

tebal silinder (ts) $= \dfrac{Pi.di}{2(f.E - 0{,}6Pi)} + C$

$= \dfrac{30{,}8808 \times 432{,}3691}{2 \times [(18750 \times 0{,}8000)-(0{,}6 \quad 30{,}881)]} + \dfrac{1}{16}$

$= 0{,}5081 \quad x \quad \dfrac{1}{16}$

$= \dfrac{0{,}5081}{16} \approx \dfrac{3}{16}$

Standarisasi do

do $=$ di $+$ 2 ts

$= 432{,}369 + (2 \times \dfrac{3}{16})$

$= 432{,}744$ in

Standarisasi dengan Tabel 5.7, Brownell and Young, hal 89

do = 240

icr = 14 7/16

r = 180

ts = 1,1250

maka :

di_{baru} = do - ts

$= 432{,}744 - (2 \times 1{,}1250)$

$= 430{,}4941$ in

$= 35{,}8745$ ft

Cek hubungan Ls dengan di:

Volume tangki $= (\dfrac{\pi}{4} \times di^2 \times Ls) + 0{,}0847 \quad di^3$

$59040{,}2703 = (\dfrac{3{,}14}{4} \times 35{,}8745^2 \times Ls) + 0{,}0847 \quad x \quad 35{,}875$

$59040{,}2703 = 1010{,}2795 \; Ls + 3910{,}5806$

$55129{,}6897 = 1010{,}2795 \; Ls$

$Ls = 54{,}5688$ ft

$\dfrac{Ls}{di} = \dfrac{54{,}5688}{35{,}8745} = 1{,}5 < 1{,}5$ (memenuhi)

e. Menghitung tinggi silinder

Tinggi silinder (Ls) = 1.5 di

= 1,5 × 430,4941

= 645,741 in

= 53,8118 ft

f. Menghitung tutup atas silinder (standar dished)

$$tha = \frac{0{,}8850 \times Pi \times r}{f.\ E - 0.1.\ Pi} + C$$

$$= \frac{0{,}8850 \times 30{,}8808 \times 180}{[(18750 \times 0{,}8) - (0{,}1 \times 30{,}8808)]} + \frac{1}{16}$$

$$= \frac{4919{,}3139}{14996{,}9119} + \frac{1}{16}$$

$$= 0{,}3905 \times \frac{16}{16}$$

$$= \frac{6{,}2483}{16} \approx \frac{3}{16}$$

Tinggi tutup atas (ha) = 0,169 x di baru

= 0,169 x 430,49

= 72,7535 in

g. Menghitung tinggi storage

Tinggi storage (H) = tinggi silinder + tinggi tutup atas

= 645,741 + 72,7535

= 718,4946 in

= 59,8746 ft

Spesifikasi alat :

Nama alat	:	Storage CH2O2 (F-122)
Fungsi	:	Menampung sementara CH2O2 sebelum masuk ke dalam heater (E-124)
Type	:	Tangki silinder vertikal, tutup atas standar dished tutup bagian bawah flat (dasar)
Bahan konstruksi	:	Stainless steel SA 240 Grade M Type 316
Volume tangki	:	59040,2703 ft^3
Diameter dalam (di)	:	430,4941 in
Diameter luar (do)	:	240 in

Tebal silinder (ts)	:	1,1250	in
Tinggi silinder (Ls)	:	645,7411	in
Tebal tutup atas (tha)	:	3/16	in
Tinggi tutup atas (ha)	:	72,7535	in
Tinggi Storage (H)	:	718,4946	in

13. Pompa Sentrifugal (L-123)

Fungsi = Untuk mengalirkan CH_2O_2 dari tangki penyimpanan (F-122) menuju heater (E-124)

Tipe = Centrifugal pump

Direncanakan =

Bahan konstruksi: = Comercial Steel

Jumlah = 1 buah

Dasar Perhitungan:

Suhu (T) = 30 °C = 303,150 K

Tekanan (P) = 1 atm

Densitas = 1,34 g/cm³ = 83,8408 lb/ft³

Viscocitas = 0,8320 Cp = 0,00056 lb/ft.s

Rate liquid = 23571,3362 lb/jam

Perhitungam:

Menghitung Rate Volumetrik (Q)

$$Q = \frac{\text{Rate bahan masuk}}{\rho \text{ bahan masuk}}$$

$$= \frac{23571,3362}{83,8408}$$

= 281,1441 ft³/jam

= 0,0759 ft³/s

= 34,0702 gpm

$Di_{optimum}$ = 3,9 $Q^{0,45}$ x $\rho^{0.13}$ *(Pers 15 "Petters & Timmerhaus" hal 496)*

= 3,9 x $[0,0759]^{0,45}$ x $[83,8408]^{0,13}$

= 2,1739 in

= 0,1812 ft

Untuk pipa ukuran 2 1/2 in sch 80

Dari *Geankoplis* , tabel A.5.1 , hal 892 didapatkan:

OD	=	2,8750	in	=	0,2396	ft
ID	=	2,3230	in	=	0,1936	ft
A	=	0,0294	ft^2			

Menentukan Kecepatan Aliran Fluida (v)

Kecepatan aliran fluida (v) $= \dfrac{Q}{A}$

$= \dfrac{281,1}{0,0294}$

= 9548,3530 ft/jam

= 2,57806 ft/s

- Menentukan Bilangan Reynold (N_{Re}) $= \dfrac{D \times v \times \rho}{\mu}$

$= \dfrac{0,1936 \times 2,5781 \times 83,8408}{0,0006}$

= 74949,6 ≥ 2100 (aliran turbulen)

Dari *Geankoplis, fig. 2.10 Hal 88* didapatkan

Equivalent rougness (ε) = 0,00005

Relative roungness $\left[\dfrac{\varepsilon}{D}\right]$ = 0,0002 *(Geankoplis, Tabel 2-10.1 Hal 94*)

Faktor friksi (f) $= \dfrac{16}{N_{Re}}$ = 0,00021 *(Geankoplis, Tabel 2-10.1 Hal 94*)

- Menentukan Panjang pipa

Asumsi:

Panjang pipa lurus	=	75 ft
elbow 90°	=	2 buah
Globe valve	=	1 buah
Tee	=	1 buah

Perhitungan:

- Panjang pipa lurus = 86 ft
- elbow 90° = 2 buah

Le/D = 75

Le = 35 ID (*Geankoplis, Tabel 2-10.1 Hal 93*)

= 35 x 0,1936 x 2 ft

= 13,5508 ft

= 2 buah

- Globe valve` = 1 buah

Le/D = 300 (wide open) (*Geankoplis, Tabel 2-10.1 Hal 93*)

Le = 13 ID

= 13 x 0,1936 x 1 ft

= 2,5166 ft

- Tee = 1 buah

Le/D = 50 ID (*Geankoplis, Tabel 2-10.1 Hal 93)*

Le = 50 x 0,1936 x 1 ft

= 9,6792 ft

Panjang pipa total (L) = Pipa lurus + elbow 90° + globe valve + tee

= 86 + 13,5508 + 2,5166 + 9,6792

= 111,7466 in

- Menentukan friksion Loss

1. Friksi pada pipa lurus

$$F_f = 4_f \frac{\Delta L}{D} \times \frac{V^2}{2g_c}$$ *(Geankoplis, Persamaan 2.10-6 Hal 86)*

$$= 4 \times 0,0030 \times \frac{75}{0,1936} \times \frac{(2,5781)^2}{2 \times 32,174}$$

$$= 4 \times 0,0030 \times 387,43 \times \frac{1931,1982}{64,348}$$

= 139,5296 lbf.ft/lbm

2. Sudden Contraction

Karena tangki sangat besar maka A_1 = 0

$$hc = 0,55 \times [1 - 0] \times \frac{(2,5781)^2}{2 \times 1 \times 32,172}$$

$$= 0,55 \times [1 - 0] \times \frac{(2,5781)^2}{2 \times 1 \times 32,172}$$

$$= 0,55 \times 1 \times \frac{1931,1982}{64,3440}$$

= 16,507507 lbl.ft/lbm

3. Sudden Expansion

$$h_{ex} = \left[1 - \frac{A2}{A1} \right] \times \frac{v_2^{\,2}}{2 \times \alpha \times gc}$$ (Geankoplis, Tabel 2.10.1 Hal 93)

$$= [1 - 0] \times \frac{(2{,}5781)^2}{2 \times 1 \times 32{,}172}$$

$$= 1 \times \frac{1931{,}1982}{64{,}3440}$$

$$= 30{,}0136 \text{ lbf.ft/lbm}$$

4. Elbow 90°, 2 buah

Kf = 0,75 (*Geankoplis, Tabel 2.10.1 Hal 93*)

$$hf = 1\, Kf \frac{v_2}{2gc}$$ (*Geankoplis, Pers 2.10.1 Hal 94*)

$$= 1 \times 0{,}75 \frac{(2{,}5781)^2}{2 \times 32{,}172}$$

$$= 1 \times 0{,}75 \times \frac{1931{,}1982}{64{,}344}$$

$$= 22{,}5102 \text{ lbf.ft/lbm}$$

5. Tee, 1 buah

Kf = 1

$$hf = 1\, Kf \frac{v_2}{2gc}$$

$$= 1 \times 1 \frac{(2{,}5781)^2}{2 \times 32{,}172}$$

$$= 1 \times \frac{6{,}6464}{64{,}3440}$$

$$= 0{,}1032943 \text{ lbf.ft/lbm}$$

Total fraksi (∑F) = $F_f + h_c + h_{ex} + h_f$ elbow 90° + hf globe valve

Total fraksi (∑F) = 139,5296 + 16,5075 + 30,0136 + 22,5102 + 0,103294

= 208,5610 lbf.ft/lbm

e. Menentukan daya pompa

Direncanakan:

ΔZ = 30 ft

ΔP = 30 lb/ft^2

v_1 = 0 ft/detik (karena P_1=P_2)

v_2 = 2,57806 ft/detik (karena fluida diam)

$\frac{\varepsilon}{D}$ = 0,0002

Hukum Bernouli

$$\frac{\Delta P}{\rho} + \Delta Z \left[\frac{g}{gc} \right] + \frac{v_2^2}{2 \times \alpha \times gc} + (\sum F) = - Ws$$

$$0 + 30 (1) + \frac{(2,5781)^2}{2 \times 1 \times 32,172} + 208,5610 = - Ws$$

$$- Ws = 30 + \frac{6,6464}{64,3440} + 208,5610 =$$

$- Ws =$ 238,66428 lbf.ft/lbm

Dengan: Capacity = 34,0702 gal/menit

Dari Fig 14.36, Hal. 520, Petters & Timmerhause, didapatkan:

Efisiensi pompa (η) = 40%

$- Ws = - \eta Wp$

238,6643 = - 40% Wp

Wp = 596,6607 ft.lb/lbm

mass flow rate (m) = Q x ρ

= 0,0759 x 83,8408

= 6,3643 lbm/s

$$WHp = Wp \times m \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

$$WHp = 596,6607 \times 6,3643 \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

WHp = 6,9042 hp

$$BHp = \frac{WHp}{\eta}$$

$$= \frac{6,9042}{40\%}$$

= 17,2605 Hp = 17 Hp

Dari Fig 14.38 Hal. 521, Petters & Timmerhause, didapatkan:

Spesifikasi Pompa Sentrifugal = 89%

$$= \frac{\text{Pump horsepower}}{\text{Efisiensi motor}}$$

$$= \frac{17,2605}{89\%}$$

= 19,3938 Hp ≈ 19,5 Hp

Spesifikai Pompa Sentrifugal

Fungsi		:	Untuk mengalirkan CH2O2 menuju heater (E-124)				
Kode alat		:	L-123				
Tipe		:	Centrifugal pump				
kapasitaas		:	34,0702 gpm				
Suhu Operasi		:	303,150 K				
Tekanan Operasi		:	1 atm				
Efisiensi Pompa		:	89%				
ΔP		:	30 lb/ft²				
Dimensi	NPS	:	2 1/2 in	OD :	2,8750	A :	0,0294
	Sch	:	40	ID :	2,3230		

14 Heater (E-124)

Fungsi : Untuk memanaskan CH2O2 sebelum masuk Netralizer (R-120)

Tipe : Double pipe Heat exchanger

Direncanakan:

- faktor kekotoran gabungan minimum (Rd) = 0,0025 jam. Ft² (*kern* , Halaman 107)
- penurunan tekanan aliran maksimum (Δp) = 10 psi
- ΔP maksimum steam = 2 psi
- Digunakan pipa ukuran 1 in
- pipa : Steam
- Anulus : CH2O2

Dasar perencanaan:

Dari Appendix B dan C didapatkan data sebagai berikut:

- Masssa bahan masuk (M)	=	10691,888 kg/jam						
	=	23571,336 lb/jam						
	=							
- Suhu bahan masuk (t_1)	=	30	°C	=	86	°F	=	303,15 K
- Suhu bahan keluar (t_2)	=	60	°C	=	140	°F	=	333,2 K
- Kebutuhan steam (m)	=	174,78426 kg/jam						
	=	385,329 lb/jam						
- Panas yang dibawah steam	=	8835,1414 kj/jam						

= 8374,0972 btu/jam

- steam masuk pada suhu (T_1) = 130 ℃ = 266 ℉
- Steam keluar pada suhu (T_2) = 130 ℃ = 266 ℉
- Beban Panas = 379911,0781 = 150662,705 Btu/jam
- Pipa = Steam
- Anulus = CH2O2

Perhitungan

A. Menghitung Δt

$\Delta t_1 = T_1 - t_2 = 266 - 140$ ℉ = 126 ℉

$\Delta t_2 = T_2 - t_1 = 266 - 86$ ℉ = 180 ℉

$$\Delta T_{LM} = \frac{\Delta t_1 - \Delta t_2}{\ln \Delta t_1 / \Delta t2}$$

$$= \frac{126 - 180}{\ln \frac{126}{180}}$$

= 151,3984 ℉

B. Menghitung suhu Kalorik (T_c dan t_c)

$Tc = (T_1 + T_2)/2$ = 266 ℉ = 130 ℃

$tc = (t1 + t2)/2$ = 156 ℉ = 69 ℃

$$= \frac{130 - 69}{\ln \frac{130}{69}}$$

= 96,2320 ℉

C. Trial U_D

- Asumsi UD = 100,0000 Btu/jam.ft².°F

$$A = \frac{Q}{U_d \cdot \Delta t}$$

$$= \frac{150.662,7055 \text{ Btu/jam}}{100,0000 \text{ Btu/jam.ft}^2.°F \times 96,23\ °F}$$

= 15,6562 ft²

D Trial ukuran double pipe:

dicoba ukuran double pipe 2 1/2 'x 1 1/4" IPS sec. 40 dengan aliran steam

Bagian pipa anulus (Kern tabel 6.2 ha 110)

a_{an} = 2,63 in^2 = 0,0183 ft^2

de	=	2,02	in	=	0,1683	ft
de'	=	0,81	in	=	0,0675	ft

Bagian Pipa (Kern, tabel 11 hal 844)

ap	=	1,5	in^2	=	0,0104	ft^2
di	=	1,38	in	=	0,1150	ft
do	=	1,66	in	=	0,1383	ft
a"	=	0,435	ft^2/ft	=		

<table>
<tr><th colspan="2">Evaluasi Perpindahan Panas</th></tr>
<tr><th>Annulus, CH2O2</th><th>Hot fluida,inner pipe ,steam</th></tr>
<tr><td>
1. Menghitung Nre anulus

$Gaan = \frac{m}{a_{an}}$
$= \frac{23571,336 \text{ lb/jam}}{0,0183 \text{ ft}^2}$
$= 1290597,9 \text{ lb/jam.ft}^2$

μ pada tc = 86 °F
μ = 0,524 Cp
(fig.24"kern",hal 834)

$N_{Re} = \frac{G_{AA} \text{ x di}}{\mu \text{ x } 2,42}$
$= \frac{1290597,9 \text{ x } 0,1683}{0,5240 \text{ x } 2,42}$
= 171322,51

2. JH = 76 (fig 24" kern" hal 834
3. Menghitung harga koefisien film
Cp = 0,9989 Btu/lb°F
k = 0,356 Btu/jam.ft²°F/ft

$\left(\frac{Cp\ \mu}{k}\right)^{1/3} = \left(\frac{1,00 \times 0,5}{0,3560}\right)^{1/3}$
= 1,1371
$ho = \frac{Jh \text{ x K x}}{} \left(\frac{Cp.\mu}{}\right)^{1/3}$
</td><td>
1. Menghitung N_{Re} pipa

$G_p = \frac{m}{a_p}$
$= \frac{150662,7055 \text{ lb/jam}}{0,0104 \text{ ft}^2}$
= 14463619,7264 lb/jam ft2

μ pada T_c = 266 °F
= 0,998 cp
(Geankoplis, tabel A.2-4, hal 855)

$NRe_p = \frac{G_p \times di}{\mu \text{ x } 2,42}$
$= \frac{14463619,7264 \text{ x } 0,1150}{0,9980 \text{ x } 2}$
= 688698,1685

2. JH = 42 (fig 24" kern" hal 834
3. Menghitung harga koefisien film
Cp = 0,234 Btu/lb°F
k = 0,356 Btu/jam.ft²°F/ft

3. Harga koefisien perpindahan panas untuk steam didapatkan
hi = 7,3482 Btu/jam.ft²°F
</td></tr>
</table>

De (k)	hio = hi x (ID/OD)
= 182,76565	= 8,8391453 Btu/jam ft^{2} ^{o}F
$\frac{ho}{\varphi s}$ = 513 Btu/jam ft^{2}°F	

E. Menghitung clean overall coefficient (U_C)

$$U_C = \frac{ho \times hio}{ho + hio}$$

$$= \frac{182,8 \times 8,8391}{182,8 + 8,8391}$$

$$= 8,4314 \text{ Btu/jam ft}^2\text{°F}$$

F. Menghitung design overall coefficiet (U_D)

$$Rd = \frac{U_C - U_D}{U_C \times U_D}$$

$$\frac{1}{U_D} = \frac{1}{U_C} + Rd$$

$$\frac{1}{U_D} = \frac{1}{8,431} + 0,0010$$

$$\frac{1}{U_D} = 0,1196$$

$$U_D = 8,361 \text{ Btu/jam ft}^2\text{°F}$$

G. Menghitung luas permukaan (A) yang diperlukan

$$A = \frac{Q}{U_D \times \Delta t} = \frac{150662,7055}{8,3609 \times 180,0000} = 100,11085 \text{ ft}^2$$

$$L = \frac{A}{a''} = \frac{100,11}{0,4350} = 256,32 \text{ ft}$$

H. Menghitung dirt factor (Rd) yang terpakai

$$Rd = \frac{U_C - U_D}{U_C \times U_D}$$

$$= \frac{8,4314 - 8,3609}{8,4314 \times 8,3609}$$

$$= 0,001 \text{ jam ft}^2 \text{ °F/Btu}$$

I. Mencari panjang ekonomis

dengan mencari over design yang terkecil dari panjang pipa standart

L (ft)	n	n_{pakai}	L_{baru}	A_{baru}	$U_{D\ baru}$	Rd_{baru}	$Rd_{over\ desain}$
12	24	11	256,32	111,50	0,0090	-1000	-250001
17	34	8	256,32	111,50	0,0090	-1000	-250001
20	40	6	256,32	111,50	0,0090	-1000	-250001

Karena over desainnya sama, maka dipilih DPHE dengan jumlah hairpin paling sedikit.

L = 20 ft dan n = 6 buah

Evaluasi Δp

Annulus

1. Pada NRe_{an} = 171322,5052

$$f = 0,0035 + \frac{0,264}{NRe^{0,42}}$$

$$= 0,0035 + \frac{0,264}{157,8345}$$

$$= 0,0052$$

2. ρ = 68,3230 lb/ft^3

$$\Delta P_1 = \frac{4 \cdot f \cdot G_{an}^2 \cdot L}{2 \cdot g \cdot \rho^2 \cdot do} \times \frac{\rho}{144}$$

$$= 5,8812 \times 0,4745$$

$$= 2,7904 \text{ Psi}$$

3. $$V = \frac{G_{an}}{3600 \times \rho}$$

$$= \frac{171322,5052}{3600 \times 68,323}$$

$$= 0,0995$$

$$\Delta P_n = n \times \left(\frac{V^2}{2 \cdot gc}\right) \times \left(\frac{\rho}{144}\right)$$

$$= 6 \times 0,0002 \times 0,4745$$

$$= 0,0005 \text{ Psi}$$

$$\Delta P_{an} = \Delta P_1 + \Delta P_n$$

Inner

1. Pada NRe_p = 688698,1685

$$f = 0,0035 + \frac{0,264}{NRe^{0,42}}$$

$$= 0,0035 + \frac{0,264}{283,12}$$

$$= 0,0044$$

2. ρ = 997,622 kg/m^3

= 62,2516 lb/ft^3

$$\Delta P_p = \frac{4 \cdot f \cdot G_p^2 \cdot L}{2 \cdot g \cdot \rho^2 \cdot do} \times \frac{\rho}{144}$$

$$= 1,041 \times 0,4323$$

$$= 0,4499 \text{ Psi}$$

$\Delta P_p < \Delta P_{allow}$

$0,4499 < 2$

Memadai

= 2,7904 + 0,0005 = 2,7909 Psi ΔP_{an} < ΔP_{allow} 2,7909 < 10 Memadai	

Spesifikasi alat :

Nama alat	:	Heater (E-124)						
Fungsi	:	Menaikkan suhu CH2O2 sebelum masuk ke Netralizer (R-120)						
Tipe	:	Double pipe heat exchanger						
Bahan konstruksi	:	Carbon steel						
Media pemanas	:	Steam						
Kapasitas	:	10691,88796 kg/jam						
Rate steam	:	174,7843 kg/jam						
Ukuran	:	3" × 2" IPS sch. 40						
Dimensi	:	Bagian anulus			Bagian pipa			
		a_{an}	=	2,63 in^2	a_p	=	1,5	in^2
		de	=	2,02 in	di	=	1,4	in
		de'	=	0,81 in	do	=	1,7	in
					a''	=	0,4	ft^2/ft
Jumlah hair pin	:	6 buah						
Jumlah	:	1						

15. Evaporator (V-130 A)

Fungsi : Meningkatkan konsentrasi C(CH2OH)4

Bahan Konstruksi : *Carbon steel SA - 283 Grade C*

Jenis : *Vertical - tube evaporator*

Bentuk : Silinder vertical dengan alas dan tutup ellipsoidal

Jumlah : 1 unit

Menentukan Jumlah Tube

Steam yang digunakan adalah steam jenuh pada suhu 130 ^{0}C, direncanakan menggunakan evaporator efek tunggal dengan 3/4 in OD tube, 1 5/16 in triangular pitch

Panas yang diberikan steam = 10.317.304,6824 Kkal/jam x 3,8910 Kkal/jam

	=	40.144.632,5191 Btu/jam		
Kebutuhan uap	=	14.395,8968 Kg		
Ud	=	250,0000 Btu/jam.ft².°F		
Temperatur Steam Masuk	=	130,00 °C	=	266,00 °F
Temperatur Steam Keluar	=	130,00 °C	=	266,00 °F
Temperatur Campuran Masuk	=	60,00 °C	=	140,00 °F
Temperatur Campuran Keluar	=	100,00 °C	=	212,00 °F

$$\text{LMTD} = \frac{\Delta t_1 - \Delta t_2}{\text{Ln}\,(\Delta t_1/\Delta t_2)}$$

$$= \frac{(266{,}00\ °F - 212{,}00\ °F) - (266{,}00\ °F - 140{,}00\ °F)}{\ln \dfrac{266{,}00\ °F - 212{,}00\ °F}{266{,}00\ °F - 140{,}00\ °F}}$$

$$= 84{,}98\ °F$$

$$A = \frac{Q}{U.\Delta T}$$

$$= \frac{40.144.632{,}5191\ \text{Btu/jam}}{250{,}0000\ \text{Btu/jam.ft}^2.°F \times 84{,}98\ °F}$$

$$= 1.889{,}6923\ \text{ft}^2$$

Dipilih pipa :

Panjang (L)	=	20,0000 ft		
OD	=	0,7500 in	=	0,0625 ft
BWG	=	16,0000		
ID	=	0,6200 in	=	0,0517 ft
a't	=	0,3020 in²	=	0,0021 ft²
a''	=	0,1963 ft²/lin.ft		*(Tabel 10.Kern)*

$$\text{Jumlah tube (Nt)} = \frac{A}{L \times a''}$$

$$= \frac{1.889{,}6923\ \text{ft}^2}{20{,}0000\ \text{ft} \times 0{,}1963\ \text{ft}^2/\text{lin.ft}}$$

Nt = 481,3276 tube

Dari tabel 9 Kern, didapat Nt yang mendekati adalah

Nt = 482,0000 tube

Menentukan ukuran evaporator

Laju Alir Masuk	=	80.934,5516 Kg/jam
Densitas Larutan	=	1.206,2800 Kg/m³

Faktor Keamanan = 20%

Waktu Tinggal dalam evaporator diperkirakan 0,5000 jam

Volume Umpan = $\frac{80.934,5516 \text{ Kg/jam} \times 0,5000 \text{ jam}}{1.206,2800 \text{ Kg/m}^3}$

= 33,5472 m^3

Laju alir uap masuk = 14.395,8968 Kg/jam

Steam masuk ke tube, volume untuk steam = volume tube (pipa)

Volume tube = Nt x Luas penampang x L

Luas Penampang = $\frac{\pi \times D^2}{4}$

= $\frac{3,1428571 \times (0,6200 \text{ in})^2}{4}$

= 0,3020 ft^2

Maka volume tube = 482,0000 x 0,3020 ft^2 x 20,0000 ft

= 2.911,5554 ft^3 x 0,0283 m^3/ft^3

= 82,4461 m^3

Volume tangki evaporator = Volume umpan + Volume tube

= 33,5472 m^3 + 82,4461 m^3

= 115,9932 m^3

Faktor kelonggaran dalam tangki diambil 20% sehingga kapasitas tangki

V_t = (1+20%) x V_c *(Brownell, 1969)*

= (1+20%) x 115,9932 m^3

= 139,1919 m^3

Dipilih tangki dengan perbandingan tinggi terhadap diameter ;

H_s : D = 2 : 1

h_s : D = 1 : 6

Volume tangki

V_t = $V_{slinder} + V_{Ellipsoidal}$

V_t = $\frac{\pi \cdot D^2 \cdot H}{4} + 2 \cdot \frac{\pi \cdot D^2 \cdot h}{6}$

= $\frac{3,14 \cdot \quad 2 \cdot D^3}{4} + 2 \cdot \frac{3,14 \quad 1/6 \cdot D^3}{6}$

139,1919 m^3 = 1,5714 D^3 + 0,1746 D^3

D^3 = $\frac{139,1919 \text{ m}^3}{1,5714 + 0,1746}$

D^3	=	79,7190 m^3
D	=	$\sqrt[3]{79,71898679}$
	=	4,3038 m x 3,2808 ft/m
	=	14,1201 ft
	=	4,3038 m x 39,3700 in/m
	=	169,4412 in
Tinggi tangki ;		
Tinggi slinder, H_s	=	2 . D
	=	2 x 4,3038 ft/m
	=	8,6076 m x 3,2808 ft/m
	=	28,2402 ft
Tinggi ellipsoidal, h_s	=	1/6 . D
	=	1/6 x 4,3038 m
	=	0,7173 m x 3,2808 ft/m
	=	2,3533 ft
Tinggi total tangki, H_t	=	H_s + 2 . h_s
	=	8,6076 m + (2 x 0,7173 m)
	=	10,0422 m x 3,2808 ft/m
	=	32,9469 ft
Tinggi cairan, H_c	=	$\frac{V_c \times 4}{3,14 \times D^2}$
	=	$\frac{115,9932\ m^3 \times 4}{3,1429 \times (4,3038\ m)^2}$
	=	7,9700 m x 3,2808 ft/m
	=	26,1483 ft
Tekanan hidrostatis, P_h	=	ρ x g x H_c
	=	1.206,2800 Kg/m³ x 9,8000 m/s² 7,9700 m
	=	94.218,1053 N/m² x $\frac{14,6960\ Psi}{1,01325 \times 10^5\ N/m^2}$
	=	13,6652 Psi
Tekanan sistem, P_s	=	1,0000 atm x 14,6960 Psi/atm
	=	14,6960 Psi

Faktor keamanan = 20%

Tekanan total desain, P_t = $(P_h + P_s) \times (1 + 0,2)$

= (13,6652 Psi + 14,6960 Psi) x (1 + 0,2

= 34,0334 Psi

Diameter tangki, Dt = 169,4412 in

Max Allowable Stress , F = 13.800,0000 Psi

Effisiensi sambungan, E = 0,85

Faktor korosi, C = 0,0060 in

Umur alat, n = 20 tahun

Tebal plate dinding tangki, t_H

$$t = \frac{P \times 0,5\ D_t}{F.E - 0,6\ P} + c.n$$

$$= \frac{34,0334 \text{ Psi} \times 0,50 \times 169,4412 \text{ in}}{(13.800 \text{ Psi} \times 0,85) - (0,6 \times 34,0334 \text{ Psi})} + (0,006 \text{ in} \times 20 \text{ tahun})$$

= 0,3662 in x 2,5400 cm/in

= 0,9302 cm

maka diperoleh OD = Dt + 2t

= 170,1736 in x 0,0254 m/in

= 4,3224 m

Tebal plate tutup tangki, t_E

$$t = \frac{P \times D_t}{2\{(F.E) - (0,2\ P)\}} + c.n$$

(Timmerhaus, 1991, hal. 537)

$$= \frac{34,0334 \text{ Psi} \times 169,4412 \text{ in}}{2[(13.800 \text{ Psi} \times 0,85) - (0,2 \times 34,0334 \text{ Psi})]} \quad (0,006 \text{ in} \times 20 \text{ tahun})$$

= 0,3660 in x 2,5400 cm/in

= 0,9295 cm

Spesifikasi Tangki Evaporator

Diameter tangki, D = 4,3038 m

Tinggi tangki total, H_t = 10,0422 m

Tebal plate, t = 0,3662 in

Kapasitas, V_t = 139,1919 m^3

Bahan kontruksi = *Carbon steel SA-283*

16. Evaporator (V-130 B)

Fungsi : Meningkatkan konsentrasi C(CH2OH)4

Bahan Konstruksi : *Carbon steel SA - 283 Grade C*

Jenis : *Vertical - tube evaporator*

Bentuk : Silinder vertical dengan alas dan tutup ellipsoidal

Jumlah : 1 unit

Menentukan Jumlah Tube

Steam yang digunakan adalah steam jenuh pada suhu 120,2 ^{0}C, direncanakan menggunakan evaporator efek tunggal dengan 3/4 in OD tube, 1 5/16 in triangular pitch

Panas yang diberikan steam	=	11.182.061,0409 Kkal/jam x 3,9810 Kkal/jam		
	=	44.515.785,0039 Btu/jam		
Kebutuhan uap	=	13.679,7135 Kg		
Ud	=	250,0000 Btu/jam.ft².°F		
Temperatur Steam Masuk	=	130,00 °C	=	266,00 °F
Temperatur Steam Keluar	=	130,00 °C	=	266,00 °F
Temperatur Campuran Masuk	=	100,00 °C	=	212,00 °F
Temperatur Campuran Keluar	=	50,00 °C	=	122,00 °F

$$LMTD = \frac{\Delta t_1 - \Delta t_2}{Ln\ (\Delta t_1/\Delta t_2)}$$

$$= \frac{(266{,}00\ °F - 122{,}00\ °F) - (266{,}00\ °F - 212{,}00\ °F)}{\ln \dfrac{266{,}00\ °F - 122{,}00\ °F}{266{,}00\ °F - 212{,}00\ °F}}$$

$$= 91{,}76\ °F$$

$$A = \frac{Q}{U.\Delta T}$$

$$= \frac{44.515.785{,}0039\ Btu/jam}{250{,}0000\ Btu/jam.ft^2.°F \times 91{,}76\ °F}$$

$$= 1.940{,}5504\ ft^2$$

Dipilih pipa :

Panjang (L)	=	20,0000 ft		
OD	=	0,7500 in	=	0,0625 ft
BWG	=	16,0000		
ID	=	0,6200 in	=	0,0517 ft
a't	=	0,3020 in²	=	0,0021 ft²
a''	=	0,1963 ft²/lin.ft		*(Tabel 10.Kern)*

$$Jumlah\ tube\ (Nt) = \frac{A}{L \times a''}$$

$$= \frac{1.940{,}5504\ ft^2}{}$$

$$= \frac{}{20{,}0000 \text{ ft} \quad x \quad 0{,}1963 \text{ ft}^2/\text{lin.ft}}$$

Nt = 494,2818 tube

Dari tabel 9 Kern, didapat Nt yang mendekati adalah

Nt = 495,0000 tube

Menentukan ukuran evaporator

Laju Alir Masuk = 80.934,5516 Kg/jam

Densitas Larutan = 1.206,2800 Kg/m³

Faktor Keamanan = 20%

Waktu Tinggal dalam evaporator diperkirakan 0,5000 jam

$$\text{Volume Umpan} = \frac{80.934{,}5516 \text{ Kg/jam} \quad x \quad 0{,}5000 \text{ jam}}{1.206{,}2800 \text{ Kg/m}^3}$$

= 33,5472 m³

Laju alir uap masuk = 13.679,7135 Kg/jam

Steam masuk ke tube, volume untuk steam = volume tube (pipa)

Volume tube = Nt x Luas penampang x L

$$\text{Luas Penampang} = \frac{\pi \times D^2}{4}$$

$$= \frac{3{,}1428571 \quad x \quad (0{,}6200 \text{ in})^2}{4}$$

= 0,3020 ft²

Maka volume tube = 495,0000 x 0,3020 ft² x 20,0000 ft

= 2.990,0829 ft³ x 0,0283 m³/ft³

= 84,6697 m³

Volume tangki evaporator = Volume umpan + Volume tube

= 33,5472 m³ + 84,6697 m³

= 118,2169 m³

Faktor kelonggaran dalam tangki diambil 20% sehingga kapasitas tangki

V_t = (1+20%) x V_c *(Brownell, 1969)*

= (1+20%) x 118,2169 m³

= 141,8603 m³

Dipilih tangki dengan perbandingan tinggi terhadap diameter ;

H_s : D = 2 : 1

h_s : D = 1 : 6

Volume tangki

V_t = $V_{slinder} + V_{Ellipsoidal}$

$$V_t = \frac{\pi \cdot D^2 \cdot H}{4} + 2 \cdot \frac{\pi \cdot D^2 \cdot h}{6}$$

$$= \frac{3{,}14 \cdot \quad 2 \cdot D^3}{4} + 2 \cdot \frac{3{,}14 \quad 1/6 \cdot D^3}{6}$$

141,8603 m³ = 1,5714 D³ + 0,1746 D³

$$D^3 = \frac{141{,}8603 \text{ m}^3}{1{,}5714 + 0{,}1746}$$

D³ = 81,2472 m³

$D = \sqrt[3]{81{,}24724021}$

= 4,3311 m x 3,2808 ft/m

= 14,2098 ft

= 4,3311 m x 39,3700 in/m

= 170,5171 in

Tinggi tangki ;

Tinggi slinder, H_s = 2 . D

= 2 x 4,3311 ft/m

= 8,6623 m x 3,2808 ft/m

= 28,4195 ft

Tinggi ellipsoidal, h_s = 1/6 . D

= 1/6 x 4,3311 m

= 0,7219 m x 3,2808 ft/m

= 2,3683 ft

Tinggi total tangki, H_t = $H_s + 2 \cdot h_s$

= 8,6623 m + (2 x 0,7219 m)

= 10,1060 m x 3,2808 ft/m

= 33,1561 ft

$$\text{Tinggi cairan, } H_c = \frac{V_c \times 4}{3{,}14 \times D^2}$$

$$= \frac{118{,}2169 \text{ m}^3 \times 4}{3{,}1429 \times (4{,}3311 \text{ m})^2}$$

= 8,0206 m x 3,2808 ft/m

= 26,3144 ft

Tekanan hidrostatis, P_h = $\rho \times g \times H_c$

= 1.206,2800 Kg/m³ x 9,8000 m/s² 8,0206 m

= 94.816,3681 N/m² x $\frac{14,6960 \text{ Psi}}{1,01325 \times 10^5 \text{ N/m}^2}$

= 13,7520 Psi

Tekanan sistem, P_s = 1,0000 atm x 14,6960 Psi/atm

= 14,6960 Psi

Faktor keamanan = 20%

Tekanan total desain, P_t = $(P_h + P_s) \times (1 + 0,2)$

= (13,7520 Psi + 14,6960 Psi) x (1 + 0,2

= 34,1375 Psi

Diameter tangki, Dt = 170,5171 in

Max Allowable Stress , F = 13.800,0000 Psi

Effisiensi sambungan, E = 0,85

Faktor korosi, C = 0,0060 in

Umur alat, n = 20 tahun

Tebal plate dinding tangki, t_H

$$t = \frac{P \times 0,5\ D_t}{F.E - 0,6\ P} + c.n$$

$$= \frac{34,1375 \text{ Psi} \times 0,50 \times 170,5171 \text{ in}}{(13.800 \text{ Psi} \times 0,85) - (0,6 \times 34,1375 \text{ Psi})} + (0,006 \text{ in} \times 20 \text{ tahun})$$

= 0,3686 in x 2,5400 cm/in

= 0,9361 cm

maka diperoleh OD = Dt + 2t

= 171,2542 in x 0,0254 m/in

= 4,3499 m

Tebal plate tutup tangki, t_E

$$t = \frac{P \times D_t}{2\{(F.E) - (0,2\ P)\}} + c.n$$

(Timmerhaus, 1991, hal. 537)

$$= \frac{34,1375 \text{ Psi} \times 170,5171 \text{ in}}{2[(13.800 \text{ Psi} \times 0,85) - (0,2 \times 34,1375 \text{ Psi})]} \quad (0,006 \text{ in} \times 20 \text{ tahun})$$

= 0,3683 in x 2,5400 cm/in

= 0,9354 cm

Spesifikasi Tangki Evaporator

Diameter tangki, D = 4,3311 m

Tinggi tangki total, H_t = 10,1060 m

Tebal plate, t = 0,3686 in

Kapasitas, V_t = 141,8603 m³

Bahan kontruksi = *Carbon steel SA-283*

17. Pompa Sentrifugal (L-131)

Fungsi = Untuk mengalirkan keluaran evaporator ke brometik kondensor

Tipe = Centrifugal pump

Direncanakan =

Bahan konstruksi: = Comercial Steel

Jumlah = 1 buah

Dasar Perhitungan:

Suhu (T) = 60 ℃ = 333,150 K

Tekanan (P) = 1 atm

Densitas = 1,21 g/cm³ = 75,2719 lb/ft³

Viscocitas = 1,3200 Cp = 0,00089 lb/ft.s

Rate liquid = 178428,3145 lb/jam

Perhitungam:

Menghitung Rate Volumetrik (Q)

$$Q = \frac{\text{Rate bahan masuk}}{\rho \text{ bahan masuk}}$$

$$= \frac{178428{,}3145}{75{,}2719}$$

= 2370,4514 ft³/jam

= 0,6400 ft³/s

= 287,2610 gpm

$$Di_{optimum} = 3{,}9 \quad Q^{0,45} \quad x \quad \rho^{0.13}$$ *(Pers 15 "Petters & Timmerhaus" hal 496)*

$$= 3{,}9 \quad x \quad [\quad 0{,}6400 \quad]^{0,45} \quad x \quad [\quad 75{,}2719 \quad]^{0,13}$$

= 5,5952 in

= 0,4663 ft

Untuk pipa ukuran 4 in sch 40

Dari *Geankoplis* , tabel A.5.1 , hal 892 didapatkan:

OD	=	4,5000	in	=	0,3750	ft
ID	=	4,0260	in	=	0,3355	ft
A	=	0,0884	ft^2			

Menentukan Kecepatan Aliran Fluida (v)

Kecepatan aliran fluida (v) $= \dfrac{Q}{A}$

$= \dfrac{2370,5}{0,0884}$

= 26802,8735 ft/jam

= 7,23678 ft/s

- Menentukan Bilangan Reynold (N_{Re}) $= \dfrac{D \times v \times \rho}{\mu}$

$= \dfrac{0,3355 \times 7,2368 \times 75,2719}{0,0009}$

= 206335,5 ≥ 2100 (aliran turbulen)

Dari *Geankoplis, fig. 2.10 Hal 88* didapatkan

Equivalent rougness (ε) = 0,00005

Relative roungness $[\dfrac{\varepsilon}{D}]$ = 0,0001 *(Geankoplis, Tabel 2-10.1 Hal 94)*

Faktor friksi (f) $= \dfrac{16}{N_{Re}}$ = 0,00008 *(Geankoplis, Tabel 2-10.1 Hal 94)*

- Menentukan Panjang pipa

Asumsi:

Panjang pipa lurus = 75 ft

elbow 90° = 3 buah

Globe valve = 1 buah

Tee = 1 buah

Perhitungan:

- Panjang pipa lurus = 50 ft
- elbow 90° = 3 buah

Le/D = 75

Le = 35 ID (*Geankoplis, Tabel 2-10.1 Hal 93*)

= 35 x 0,3355 x 3 ft

= 35,2275 ft

= 1 buah

- Globe valve` = 1 buah

Le/D = 300 (wide open) (*Geankoplis, Tabel 2-10.1 Hal 93*)

Le = 13 ID

= 13 x 0,3355 x 1 ft

= 4,3615 ft

- Tee = 1 buah

Le/D = 50 ID (*Geankoplis, Tabel 2-10.1 Hal 93)*

Le = 50 x 0,3355 x 1 ft

= 16,7750 ft

Panjang pipa total (L) = Pipa lurus + elbow 90° + globe valve + tee

= 50 + 35,2275 + 4,3615 + 16,7750

= 106,3640 in

- Menentukan friksion Loss

1. Friksi pada pipa lurus

$$F_f = 4_f \frac{\Delta L}{D} x \frac{V^2}{2g_c}$$ (*Geankoplis, Persamaan 2.10-6 Hal 86)*

$$= 4 \text{ x } 0{,}0030 \text{ x } \frac{75}{0{,}3355} \text{ x } \frac{(7{,}2368)^2}{2 \text{ x } 32{,}174}$$

$$= 4 \text{ x } 0{,}0030 \text{ x } 223{,}55 \text{ x } \frac{1931{,}1982}{64{,}348}$$

= 80,508507 lbf.ft/lbm

2. Sudden Contraction

Karena tangki sangat besar maka A_1 = 0

$$hc = 0{,}55 \text{ x } [\ 1 - 0\ ] \text{ x } \frac{(7{,}2368)^2}{2 \text{ x } 1 \text{ x } 32{,}172}$$

$$= 0{,}55 \text{ x } [\ 1 - 0\ ] \text{ x } \frac{(7{,}2368)^2}{2 \text{ x } 1 \text{ x } 32{,}172}$$

$$= 0{,}55 \text{ x } 1 \text{ x } \frac{1931{,}1982}{64{,}3440}$$

= 16,507507 lbl.ft/lbm

3. Sudden Expansion

h_{ex} = [1 - A2] x $\frac{v_2^2}{}$ (Geankoplis, Tabel 2.10.1 Hal 93)

$$\frac{}{A1} \qquad \frac{}{2 \times \alpha \times gc}$$

$$= [\ 1 - 0\ ] \times \frac{(7{,}2368)^2}{2 \times 1 \times 32{,}172}$$

$$= 1 \times \frac{1931{,}1982}{64{,}3440}$$

$$= 30{,}0136 \text{ lbf.ft/lbm}$$

4. Elbow 90°, 4 buah

$Kf = 0{,}75$ (*Geankoplis, Tabel 2.10.1 Hal 93*)

$hf = 1\ Kf\ \frac{v_2}{2gc}$ (*Geankoplis, Pers 2.10.1 Hal 94*)

$$= 1 \times 0{,}75 \frac{(7{,}2368)^2}{2 \times 32{,}172}$$

$$= 1 \times 0{,}75 \times \frac{1931{,}1982}{64{,}344}$$

$$= 22{,}5102 \text{ lbf.ft/lbm}$$

5. Tee, 1 buah

$Kf = 1$

$hf = 1\ Kf\ \frac{v_2}{2gc}$

$$= 1 \times 1 \frac{(7{,}2368)^2}{2 \times 32{,}172}$$

$$= 1 \times \frac{52{,}3709}{64{,}3440}$$

$$= 0{,}8139209 \text{ lbf.ft/lbm}$$

Total fraksi (∑F) = $F_f + h_c + h_{ex} + h_f$ elbow 90° + hf globe valve

Total fraksi (∑F) = 80,508507 + 16,5075 + 30,0136 + 22,5102 + 0,813921

= 149,5399 lbf.ft/lbm

e. Menentukan daya pompa

Direncanakan:

ΔZ = 30 ft

ΔP = 30 lb/ft^2

v_1 = 0 ft/detik (karena $P_1=P_2$)

v_2 = 7,23678 ft/detik (karena fluida diam)

$$\frac{\varepsilon}{D} = 0{,}0001$$

Hukum Bernouli

$$\frac{\Delta P}{\rho} + \Delta Z \left[\frac{g}{gc} \right] + \frac{v_2^2}{2 \times \alpha \times gc} + (\sum F) = - Ws$$

$$0 + 30 \ (\ 1 \ ) + \frac{(\ 7{,}2368 \ )^2}{2 \times 1 \times 32{,}172} + 149{,}5399 = - Ws$$

$$- Ws = 30 + \frac{52{,}3709}{64{,}3440} + 149{,}5399 =$$

$$- Ws = 180{,}35382 \ \text{lbf.ft/lbm}$$

Dengan: Capacity = 287,2610 gal/menit

Dari Fig 14.36, Hal. 520, Petters & Timmerhause, didapatkan:

Efisiensi pompa (η) = 40%

$$- Ws = - \eta \ Wp$$

$$180{,}3538 = - 40\% \ Wp$$

$$Wp = 450{,}88455 \ \text{ft.lb/lbm}$$

mass flow rate (m) = Q x ρ

= 0,6400 x 75,2719

= 48,1756 lbm/s

$$WHp = Wp \times m \times \frac{1 \ \text{hp}}{550 \ \text{ft.lbf/s}}$$

$$WHp = 450{,}88455 \times 48{,}1756 \times \frac{1 \ \text{hp}}{550 \ \text{ft.lbf/s}}$$

$$WHp = 39{,}4939 \ \text{hp}$$

$$BHp = \frac{WHp}{\eta}$$

$$= \frac{39{,}4939}{40\%}$$

$$= 98{,}7348 \ \text{Hp} = 99 \ \text{hp}$$

Dari Fig 14.38 Hal. 521, Petters & Timmerhause, didapatkan:

Spesifikasi Pompa Sentrifugal = 89%

$$= \frac{\text{Pump horsepower}}{\text{Efisiensi motor}}$$

$$= \frac{98{,}7348}{89\%}$$

$$= 110{,}9380 \ \text{Hp} \approx 111 \ \text{Hp}$$

Spesifikai Pompa Sentrifugal

Fungsi		:	Untuk mengalirkan CH_2O_2 menuju heater (E-132)				
Kode alat		:	L-131				
Tipe		:	Centrifugal pump				
kapasitaas		:	287,2610 gpm				
Suhu Operasi		:	333,150 K				
Tekanan Operasi		:	1 atm				
Efisiensi Pompa		:	89%				
ΔP		:	30 lb/ft²				
Dimensi	NPS	:	4 in	OD :	4,5000	A :	0,0884
	Sch	:	40	ID :	4,0260		

18. Baromatik Kondensor (E-129)

Fungsi : Mengembunkan uap air dalam evaporator

Direncanakan:

- faktor kekotoran gabungan minimum(Rd) : 0,01 jam.ft^2.°F/Btu
- Δp maksimum aliran : 10 psi
- Δp maksimum steam : 2,5 psi
- Ukuran pipa : 3/4 OD BWG 16
- Susunan : Triangular, dengan Pt 1 in

Dasar perencanaan:

Dari Perhitungan Neraca Massa dan Panas didapatkan data sebagai berikut:

- Massa bahan masuk (m)	=	28075,6103	kg/jam
	=	61896,1255	lb/jam
- Q pendingin masuk	=	1171768,905	kkal/jam
	=	4649953,981	BTU/jam
- Massa pendingin	=	32122,619	kg/jam
	=	70818,253	lb/jam

Suhu pendingin masuk t1	:	30	C	=	86	F
Suhu pendingin keluar t2	:	35	C	=	95	F
Suhu uap masuk T1	:	100	C	=	212	F
Suhu uap keluar T2	:	50	C	=	122	F

Δt LMTD

$$\Delta t\ LMTD = \frac{(167-86) - (113-95)}{\ln \dfrac{(167-86)}{(113-95)}} = 64,267\ F$$

Δt = Ft x ΔtLM = 1 x 64,267142 = 64,267 F

Suhu Kalorik

$Tc = \frac{1}{2}(T1 + T2) = \frac{1}{2}(212 + 122)$

= 167 F

$tc = \frac{1}{2}(t1 + t2) = \frac{1}{2}(86 + 95)$

= 90,5 F

Tube yang digunakan berukuran 1" OD 16 BWG panjang 16 ft, susunan pipa segiempat dengan Pt = 1,25

Trial U_I = 500 btu/jft^2 F ; L = 16 ft

$A = \frac{Q}{UD\ \Delta t} = \frac{4649953{,}9809}{500 \quad 64{,}267} = 144{,}7070\ ft^2$

$Nt = \frac{A}{a'' \quad 1} = \frac{144{,}7070}{0{,}1963 \quad 16} = 46{,}0733 = 52$ buah

Nt distandardkan, dari tabel 9 hal 842 Kern. Didapatkan Ids = 8 in

n = 4 ; Nt = 46,0733 buah

$UD\ koreksi = \frac{Nt}{Nt\ standard} \times UD\ trial = \frac{46{,}0733}{52} \times 500$

= 443,0126 btu/jft^2 F

Spesifikasi :

- Fungsi : Mengembunkan uap air dalam evaporator
  Kapasitas : 28075,6103 Kg/jam
  Tipe : Triangular, dengan Pt 1 in
  A : 144,7070 ft^2

19. Jet Ejector (G-128)

Fungsi : Memvakumkan tekanan di badan II

Tipe : Single jet ejector

Bahan komstruksi : Carbon steel

Direncanakan:

- P discharge = 1 atm = 14,7 psia
- T steam = 130 C
- P steam = 5 atm = 67,62 psia
- T evap = 100 C

Diasumsikan tekanan vakum pada:

- P evaporator = 11,76 psia

Dari Perry ed 7 pers 10-90 didapat:

$\frac{W}{Wa} = \frac{Wb}{Wa}$ √(Toa x Mb)/(Tob x Ma) = 0,2 atm

Dimana: Ma = Berat molekul udara = 29

Mb = Berat molekul air = 18

$\frac{Po3}{Pob} = \frac{14,7}{11,76} = 1,25$

$\frac{Pob}{Po3} = \frac{11,76}{14,7} = 0,8$

Dari Perry ed 7 pers 10-90 didapat:

$\frac{A2}{A1} = 10$

$\frac{Wb}{Wa} = 0,15$

$\frac{W}{Wa} = \frac{Wb}{Wa}$ √(Toa x Mb)/(Tob x Ma)

$\frac{1}{Wa} = 0,15 \times \sqrt{\frac{80934,552}{28075,61}}$

$\frac{1}{Wa} = 0,15 \times \sqrt{2,8827}$

$\frac{1}{Wa} = 0,15 \times \sqrt{}\ 1,698$

$\frac{1}{Wa} = 0,2547$

Wa = 3,9265 lb/jam

= 1,7811 kg/jam

Spesifikasi alat:

Fungsi	:	Memvakumkan tekanan
Tipe	:	Single jet ejector
Rate	:	1,7811 kg/jam
Bahan	:	Carbon steel
Dimensi	:	Wb/Wa = 0,15
		Pob/Poa = 0,1176
Jumlah	:	1 buah

20. Kriztalizer (X-132)

Fungsi : untuk membentuk Kristal Pentaeritritol C(CH2OH)4

Tipe : Swenson - Walker Cryztalizer

Dasar Perencanaan

- Bahan masuk = 52.858,9414 kg/jam = 116532,8221 lb/jam
  = 32,3702 lb/s
- ρ campuran = 75,2719 lb/ft^3

- Menghitung rate volumetrik (Q)

$$Q = \frac{32,3702 \text{ lb/s}}{75,2719 \text{ lb/ft}^3}$$

$$= 0,4300 \text{ ft}^3\text{/s}$$

Suhu larutan masuk kristalizer operasi = 77,4 °C = 171,32 °F

Suhu larutan keluar kristalizer operasi = 50 °C = 122 °F

Suhu air pendingin masuk = 30 °C = 86 °F

Suhu air pendingin keluar = 40 °C = 104 °F

Menghitung

- t_1 = 30 °C = 86 °F
- t_2 = 40 °C = 104,0 °F
- T_1 = 77 °C = 171,3 °F
- T_2 = 50 °C = 122,0 °F

Δt_1 = 171 °F - 104,0 °F = 67 °F

Δt_2 = 122 °F - 86,0 °F = 36 °F

$$\text{Trial } \Delta T_{LMTD} = \frac{\Delta t_1 - \Delta t_2}{\ln \frac{\Delta t_1}{\Delta t_2}}$$

$$= \frac{67 - 36}{\ln \frac{67}{36}} = \frac{31}{\ln 1,9} = 50,037 \text{ °F}$$

Dimensi Swenson-Walker (Badger & Banchero, Hal 524)

Diameter (D) = 24 in = 2 ft

Panjang (p) = (10 - 40) ft, diambil panjang tangki kristal 36 ft

Putaran pengaduk = (5-30) rpm, diambil 30 rpm

Menentukan jumlah kristaliser berdasarkan perpindahan panas

Range U_D = (5-75) btu/jam.ft^2/°F (Kern tabel 8, hal 840)

Diambil U_D = 75 btu/jam.ft^2/°F

Pendingin (Q) = 1.848.967,7328 kkal/jam = 7.337.295,6336 btu/jam

$$A = \frac{Q}{U_D \times \Delta T_{LMTD}}$$

$$= \frac{7.337.295,6336 \text{ btu/jam}}{\ldots} = 1955,1704 \text{ ft}^2$$

$$= \frac{\quad}{75 \text{ btu/jam.ft}^2/°F} \times \frac{\quad}{50{,}037 \text{ °F}} = 1955{,}1704 \text{ ft}^2$$

$$A = \frac{1}{2} \times \pi \times D \times L$$

$$A = \frac{1}{2} \times 3{,}14 \times 0 \times L$$

$$L = \frac{1955{,}1704 \text{ ft}^2}{\frac{1}{2} \times 3{,}14 \times 2 \text{ ft}} = 622{,}6657387 \text{ ft}$$

Jumlah Kristaliser yang dibutuhkan = $\frac{L}{\text{panjang}} = \frac{622{,}67}{36} = 17{,}296 \approx 1$

Menentukan power kristaliser

Volume liquid = Rate Volumetric

= 0,4300 ft^3/s

= 1548,1589 ft^3/jam

Waktu tinggal dalam kristaliser = 1 jam

Volume bahan = 1548,1589 × 1 = 1548,1589 ft^3

Maka, power pengaduk pada Swenson-Walker Kristaliser

Power yang digunakan adalah 16 Hp tiap 1000 ft^3 bahan (Hugot, hal 694)

$$\text{Power Kristaliser} = \frac{1548{,}1589}{1000} \times 16 \text{ Hp} = 24{,}771 = 25 \text{ Hp}$$

Spesifikasi alat

Nama Alat	:	Kristaliser
Fungsi	:	Mengkristalkan aluminium sulfat
Type	:	Swenson - Walker Cryztalizer
Bahan Konstruksi	:	Carbon Steel
Diameter (D)	:	2 ft = 24 in
Panjang (L)	:	622,67 ft = 7472 in
Putaran Pengaduk	:	30 rpm
Daya	:	25 hp
Jumlah	:	1 buah

21. Pompa Sentrifugal (L-131)

Fungsi = Untuk mengalirkan keluaran netralizer ke evaporator

Tipe = Centrifugal pump

Direncanakan =

Bahan konstruksi: = Comercial Steel
Jumlah = 1 buah

Dasar Perhitungan:

Suhu (T) = 50 ℃ = 323,150 K
Tekanan (P) = 1 atm
Densitas = 974,00 g/cm³ = 60,7775 lb/ft³
Viscocitas = 1,3200 Cp = 0,00089 lb/ft.s
Rate liquid = 116532,8221 lb/jam

Perhitungam:

Menghitung Rate Volumetrik (Q)

$$Q = \frac{\text{Rate bahan masuk}}{\rho \text{ bahan masuk}}$$

$$= \frac{116532{,}8221}{60{,}7775}$$

= 1917,3666 ft³/jam
= 0,5177 ft³/s
= 232,3543 gpm

$Di_{optimum} = 3{,}9 \quad Q^{0,45} \quad x \quad \rho^{0.13}$ *(Pers 15 "Petters & Timmerhaus" hal 496)*

$= 3{,}9 \quad x \quad [\ 0{,}5177\ ]^{0,45} \quad x \quad [\ 60{,}7775\ ]^{0,13}$

= 4,9463 in
= 0,4122 ft

Untuk pipa ukuran 4 in sch 40

Dari *Geankoplis* , tabel A.5.1 , hal 892 didapatkan:

OD	=	4,5000	in	=	0,3750	ft
ID	=	4,0260	in	=	0,3355	ft
A	=	0,0884	ft²			

Menentukan Kecepatan Aliran Fluida (v)

$$\text{Kecepatan aliran fluida (v)} = \frac{Q}{A}$$

$$= \frac{1917{,}4}{0{,}0884}$$

= 21679,8097 ft/jam

= 5,85355 ft/s

- Menentukan Bilangan Reynold (N_{Re}) = $\frac{D \times v \times \rho}{\mu}$

$= \frac{0,3355 \times 5,8535 \times 60,7775}{0,0009}$

= 134759,2 ≥ 2100 (aliran turbulen)

Dari *Geankoplis, fig. 2.10 Hal 88* didapatkan

Equivalent rougness (ε) = 0,00005

Relative roungness $[\frac{\varepsilon}{D}]$ = 0,0001 *(Geankoplis, Tabel 2-10.1 Hal 94*)

Faktor friksi (f) = $\frac{16}{N_{Re}}$ = 0,00012 *(Geankoplis, Tabel 2-10.1 Hal 94*)

- Menentukan Panjang pipa

Asumsi:

Panjang pipa lurus = 75 ft

elbow 90° = 4 buah

Globe valve = 1 buah

Tee = 1 buah

Perhitungan:

- Panjang pipa lurus = 50 ft
- elbow 90° = 4 buah

Le/D = 75

Le = 35 ID (*Geankoplis, Tabel 2-10.1 Hal 93*)

= 35 x 0,3355 x 4 ft

= 46,9700 ft

= 1 buah

- Globe valve` = 1 buah

Le/D = 300 (wide open) (*Geankoplis, Tabel 2-10.1 Hal 93*)

Le = 13 ID

= 13 x 0,3355 x 1 ft

= 4,3615 ft

- Tee = 1 buah

Le/D = 50 ID *(Geankoplis, Tabel 2-10.1 Hal 93)*

Le = 50 x 0,3355 x 1 ft
= 16,7750 ft

Panjang pipa total (L) = Pipa lurus + elbow 90° + globe valve + tee
= 50 + 46,9700 + 4,3615 + 16,7750
= 118,1065 in

- Menentukan friksion Loss

1. Friksi pada pipa lurus

$$F_f = 4_f \frac{\Delta L}{D} \times \frac{V^2}{2g_c}$$ *(Geankoplis, Persamaan 2.10-6 Hal 86)*

$$= 4 \times 0,0030 \times \frac{75}{0,3355} \times \frac{(5,8535)^2}{2 \times 32,174}$$

$$= 4 \times 0,0030 \times 223,55 \times \frac{1931,1982}{64,348}$$

= 80,508507 lbf.ft/lbm

2. Sudden Contraction

Karena tangki sangat besar maka A_1 = 0

$$hc = 0,55 \times [1 - 0] \times \frac{(5,8535)^2}{2 \times 1 \times 32,172}$$

$$= 0,55 \times [1 - 0] \times \frac{(5,8535)^2}{2 \times 1 \times 32,172}$$

$$= 0,55 \times 1 \times \frac{1931,1982}{64,3440}$$

= 16,507507 lbl.ft/lbm

3. Sudden Expansion

$$h_{ex} = \left[1 - \frac{A2}{A1}\right] \times \frac{v_2^2}{2 \times \alpha \times gc}$$ (Geankoplis, Tabel 2.10.1 Hal 93)

$$= [1 - 0] \times \frac{(5,8535)^2}{2 \times 1 \times 32,172}$$

$$= 1 \times \frac{1931,1982}{64,3440}$$

= 30,0136 lbf.ft/lbm

4. Elbow 90°, 4 buah

Kf = 0,75 *(Geankoplis, Tabel 2.10.1 Hal 93)*

hf = 1 Kf $\frac{v_2}{}$ *(Geankoplis, Pers 2.10.1 Hal 94)*

$$= 1 \times 0{,}75 \frac{(5{,}8535)^2}{2 \times 32{,}172}$$

$$= 1 \times 0{,}75 \times \frac{1931{,}1982}{64{,}344}$$

$$= 22{,}5102 \text{ lbf.ft/lbm}$$

5. Tee, 1 buah

Kf = 1

$$hf = 1\ Kf \frac{v_2}{2gc}$$

$$= 1 \times 1 \frac{(5{,}8535)^2}{2 \times 32{,}172}$$

$$= 1 \times \frac{34{,}2640}{64{,}3440}$$

$$= 0{,}5325132 \text{ lbf.ft/lbm}$$

Total fraksi (∑F) = $F_f + h_c + h_{ex} + h_f$ elbow 90° + hf globe valve

Total fraksi (∑F) = 80,508507 + 16,5075 + 30,0136 + 22,5102 + 0,532513

= 149,5399 lbf.ft/lbm

e. Menentukan daya pompa

Direncanakan:

ΔZ = 30 ft

ΔP = 30 lb/ft^2

v_1 = 0 ft/detik (karena P_1=P_2)

v_2 = 5,85355 ft/detik (karena fluida diam)

$\frac{\varepsilon}{D}$ = 0,0001

Hukum Bernouli

$$\frac{\Delta P}{\rho} + \Delta Z \left[\frac{g}{gc} \right] + \frac{v_2^2}{2 \times \alpha \times gc} + (\sum F) = -\ Ws$$

$$0 + 30\ (1) + \frac{(5{,}8535)^2}{2 \times 1 \times 32{,}172} + 149{,}5399 = -\ Ws$$

$$-\ Ws = 30 + \frac{34{,}2640}{64{,}3440} + 149{,}5399 =$$

$$-\ Ws = 180{,}07241 \text{ lbf.ft/lbm}$$

Dengan: Capacity = 232,3543 gal/menit

Dari Fig 14.36, Hal. 520, Petters & Timmerhause, didapatkan:

Efisiensi pompa (η) = 40%

$$- Ws = - \eta \; Wp$$

$$180{,}0724 = - 40\% \; Wp$$

$$Wp = 450{,}18103 \text{ ft.lb/lbm}$$

$$\text{mass flow rate (m)} = Q \times \rho$$

$$= 0{,}5177 \times 60{,}7775$$

$$= 31{,}4639 \text{ lbm/s}$$

$$WHp = Wp \times m \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

$$WHp = 450{,}18103 \times 31{,}4639 \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

$$WHp = 25{,}7535 \text{ hp}$$

$$BHp = \frac{WHp}{\eta}$$

$$= \frac{25{,}7535}{40\%}$$

$$= 64{,}3838 \text{ Hp} = 99 \text{ hp}$$

Dari Fig 14.38 Hal. 521, Petters & Timmerhause, didapatkan:

Spesifikasi Pompa Sentrifugal = 89%

$$= \frac{\text{Pump horsepower}}{\text{Efisiensi motor}}$$

$$= \frac{64{,}3838}{89\%}$$

$$= 72{,}3413 \text{ Hp} \approx 111 \text{ Hp}$$

Spesifikai Pompa Sentrifugal

Fungsi	:	Untuk mengalirkan CH_2O_2 menuju heater (E-132)
Kode alat	:	L-131
Tipe	:	Centrifugal pump
kapasitaas	:	232,3543 gpm
Suhu Operasi	:	323,150 K
Tekanan Operasi	:	1 atm
Efisiensi Pompa	:	89%
ΔP	:	30 lb/ft²
Dimensi NPS	:	4 in OD : 4,5000 A : 0,0884

Sch : 40 ID : 4,0260

22. Centrefunge (H-133)

Fungsi : Memisahkan kristal Pentaeritritol dari mother liquor yang masih tercampur

Tipe : Disk Centrifuge

Dasar Perancangan

- Temperatur = 30 ^oC
- Tekanan = 1 atm
- Massa bahan masuk = 52858,94137 Kg/jam
  = 1.942,2137 lb/mnt
- ρ campuran = 974,00 lb/ft

Perhitungan

- Kapasitas dalam gal/jam = 54,2700 ft3/jam
  0,0151 ft3/detik
  = 6,7662 gal/jam

Dari tabel 18-12, hal 18-112, perry's 7^{ed}

- Diameter = 12 in
- Kecepatan = 4000 rpm

Dari perry's, 6 ^{ed} hal. Diperoleh :

Hp = 0,000000005167 x G x R^2x $(rpm)^2$

= 0,000000005167 x 1.942,2137 x 0,0434 x 16.000.000

= 6,9690 Hp

Dari fig. 14-38, Peter & Timmerhaus, hal 521, diperoleh efisie 84%

$$Hp = \frac{6,9690}{50\%}$$

= 13,938 Hp

Spesifikasi alat

Nama	:	Centrifuge
Fungsi	:	Untuk memisahkan hasil reaksi dengan impuritis yang terikut
Type	:	Disk Centrifuge
Diameter	:	12 in
Kecepatan	:	4000 rpm
power	:	14 Hp
Jumlah	:	1 Buah

24. **Screw Conveyor (J-143)**

Fungsi : Mengangkut produk pentaeritrito (J-143) menuju Bin produk (F-124C)

Tipe : *Horizontal Screw Conveyor*

Dasar pemilihan alat:

- Rate bahan masuk = 8855,14 kg/jam = 19522,0381 lb/jam
  = 8,855138382 ton/jam
- ρ produk = 1385 kg/cm^3 = 86,4240 lb/ft^3
- Faktor keamanan = 20%
- Kapasitas = 120% × 8855,14 = 10626,1661 kg/jam
  = 23426,44569 lb/jam
- Rate volumetrik $= \dfrac{\text{massa bahan}}{\rho\ \text{produk}}$

$$= \frac{23426,4457}{86,4240}$$

$= 271,0641\ ft^3/jam = 4,5177\ ft^3/menit$

Berdasarkan Perry edisi 7, hal 21-8, tabel 21-6, dipilih screw conveyor dengan spesifikasi sebagai berikut:

- Kapasitas = 15 ton/jam
- Panjang Screw = 10 ft
- Diameter Flights = 10 in
- Diameter Pipa = 2,5 in
- Diameter Shaft = 2 in
- Kecepatan putar = 55 rpm
- Diameter feed masuk = 9 in
- Hangar center = 10 ft

Perhitungan :

a. Perhitungan power :

$$Hp = \frac{C \times L \times W \times F}{3300}$$

(Banchero, pers. 16-6, hal. 7:

Dimana : C = kapasitas screw conveyor
L = panjang
W = densitas bahan
F = faktor material (termasuk keras, c = 3.5)

$$Hp = \frac{4,5177}{} \times \frac{10}{} \times \frac{86,4240}{} \times \frac{3,5}{}$$

Hp = $\frac{\quad}{3300}$

= 4,1410 Hp

b. Effisiensi motor : 84% *(Peter & Timmerhauss fig. 14.3*

$= \frac{4,1410}{84\%} =$ 4,9298 Hp

Diambil power = 5 Hp

Spesifikasi Alat:

Nama	:	Screw Conveyor (J-123D)
Fungsi	:	Untuk mengangkut produk Pentaeritritol dari Hammer Mill (C-127) menuju Bin produk (F-124C)
Tipe	:	*Horizontal Screw Conveyor*
Kapasitas	:	10626,1661 kg/jam
Bahan Konstruksi	:	*Carbon steel*
Diameter flight	:	10 in
Diameter pipa	:	2 1/2 in
Diameter shaft	:	2 in
Diameter feed masuk	:	9 in
Panjang	:	10 ft
Kecepatan putar	:	55 rpm
Hangar center	:	10 ft
Daya	:	5 Hp
Jumlah	:	1 buah

24. Pompa Sentrifugal (L-144)

Fungsi = Untuk mengalirkan keluaran centrefunge menuju UPL

Tipe = Centrifugal pump

Direncanakan =

Bahan konstruksi: = Comercial Steel

Jumlah = 1 buah

Dasar Perhitungan:

Suhu (T) = 30 °C = 303,150 K

Tekanan (P) = 1 atm

Rate liquid = 44003,8030 kg/jam

= 97010,8 lb/jam

viscositas = 1,3 cP = 0,000887 lb/ft.s

Perhitungam:

Menghitung Rate Volumetrik (Q)

$$Q = \frac{\text{Rate bahan masuk}}{\rho \text{ bahan masuk}}$$

$$= \frac{97010,7841}{86,4240}$$

= 1122,4982 ft^3/jam

= 0,3031 ft^3/s

= 136,0289 gpm

$Di_{optimum}$ = 3,9 $Q^{0,45}$ x $\rho^{0.13}$ *(Pers 15 "Petters & Timmerhaus" hal 496)*

= 3,9 x $[0,3031]^{0,45}$ x $[86,4240]^{0,13}$

= 4,0693 in

= 0,3391 ft

Untuk pipa ukuran 4 in sch 40

Dari *Geankoplis* , tabel A.5.1 , hal 892 didapatkan:

OD	=	4,5000	in	=	0,3750	ft
ID	=	4,0260	in	=	0,3355	ft
A	=	0,0884	ft^2			

c. Menentukan Kecepatan Aliran Fluida (v)

Kecepatan aliran fluida (v) $= \frac{Q}{A}$

$$= \frac{1122,5}{0,0884}$$

= 12692,1721 ft/jam

= 3,42689 ft/s

- Menentukan Bilangan Reynold (N_{Re}) $= \frac{D \times v \times \rho}{\mu}$

$$= \frac{0,3355 \times 3,4269 \times 86,4240}{0,0009}$$

= 112016,9 ≥ 2100 (aliran turbulen)

Dari *Geankoplis, fig. 2.10 Hal 88* didapatkan

Equivalent rougness (ε) = 0,00005

Relative roungness $[\frac{\varepsilon}{D}]$ = 0,0001 *(Geankoplis, Tabel 2-10.1 Hal 94)*

Faktor friksi (f) = $\frac{16}{N_{Re}}$ = 0,00014 *(Geankoplis, Tabel 2-10.1 Hal 94)*

- Menentukan Panjang pipa

  Asumsi:

  Panjang pipa lurus = 75 ft

  elbow 90° = 2 buah

  Globe valve = 1 buah

  Tee = 1 buah

  Perhitungan:

- Panjang pipa lurus = 50 ft
- elbow 90° = 2 buah

  Le/D = 75

  Le = 35 ID (*Geankoplis, Tabel 2-10.1 Hal 93*)

  = 35 x 0,3355 x 2 ft

  = 23,4850 ft

  = 1 buah

- Globe valve = 1 buah

  Le/D = 13 (*Geankoplis, Tabel 2-10.1 Hal 93*)

  Le = 13 ID

  = 13 x 0,3355 x 1 ft

  = 4,3615 ft

- Tee = 1 buah

  Le/D = 50 ID *(Geankoplis, Tabel 2-10.1 Hal 93)*

  Le = 50 x 0,3355 x 1 ft

  = 16,7750 ft

Panjang pipa total (L) = Pipa lurus + elbow 90° + globe valve + tee

= 50 + 23,4850 + 4,3615 + 16,7750

= 94,6215 ft

- Menentukan friksion Loss

  1. Friksi pada pipa lurus

$F_f = 4_f \dfrac{\Delta L}{D} \times \dfrac{V^2}{2g_c}$ *(Geankoplis, Persamaan 2.10-6 Hal 86)*

$= 4 \times 0{,}0030 \times \dfrac{75}{0{,}3355} \times \dfrac{(3{,}4269)^2}{2 \times 32{,}174}$

$= 4 \times 0{,}0030 \times 223{,}55 \times \dfrac{1931{,}1982}{64{,}348}$

$= 80{,}508507$ lbf.ft/lbm

2. Sudden Contraction

Karena tangki sangat besar maka $A_1 = 0$

$hc = 0{,}55 \times [1 - 0] \times \dfrac{(3{,}4269)^2}{2 \times 1 \times 32{,}172}$

$= 0{,}55 \times [1 - 0] \times \dfrac{(3{,}4269)^2 \; \rho}{2 \times 1 \times 32{,}172}$

$= 0{,}55 \times 1 \times \dfrac{1931{,}1982}{64{,}3440}$

$= 16{,}507507$ lbl.ft/lbm

3. Sudden Expansion

$h_{ex} = \left[1 - \dfrac{A2}{A1}\right] \times \dfrac{v_2^2}{2 \times \alpha \times gc}$ (*Geankoplis, Persamaan 2.10-15 Hal 93*)

$= [1 - 0] \times \dfrac{(3{,}4269)^2}{2 \times 1 \times 32{,}172}$

$= 1 \times 1931{,}1982$

$= 1 \times \dfrac{1931{,}1982}{64{,}3440}$

$= 30{,}0136$ lbf.ft/lbm

4. Elbow 90°, 1 buah

$Kf = 0{,}75$ (*Geankoplis, Tabel 2.10.1 Hal 93*)

$hf = 1Kf \dfrac{v_2}{2gc}$ (*Geankoplis, Pers 2.10.1 Hal 94*)

$= 1 \times 0{,}75 \dfrac{(3{,}4269)^2}{2 \times 32{,}172}$

$= 3 \times 0{,}75 \times \dfrac{1931{,}1982}{64{,}344}$

$= 67{,}5307$ lbf.ft/lbm

5. Tee, 1 buah

Kf = 1

$hf = 1\ Kf\ \frac{v_2}{2gc}$

$= 1 \times \frac{1\ (3{,}4269)^2}{2 \times 32{,}172}$

$= 1 \times \frac{11{,}7436}{64{,}3440}$

= 0,182512 lbf.ft/lbm

Total fraksi (∑F) = $F_f + h_c + h_{ex} + h_f$ elbow 90° + hf globe valve

Total fraksi (∑F) = 80,508507 + 16,5075 + 30,0136 + 67,5307 + 0,182512

= 194,7429 lbf.ft/lbm

e. Menentukan daya pompa

Direncanakan:

ΔZ = 30 ft

ΔP = 30 lb/ft^2

v_1 = 0 ft/detik (karena $P_1=P_2$)

v_2 = 3,42689 ft/detik (karena fluida diam)

$\frac{\varepsilon}{D}$ = 0,0001

Hukum Bernouli

$$\frac{\Delta P}{\rho} + \Delta Z \left[\frac{g}{gc} \right] + \frac{v_2^2}{2 \times \alpha \times gc} + (\sum F) = -\ Ws$$

$$0 + 30\ (1) + \frac{(3{,}4269)^2}{2 \times 1 \times 32{,}172} + 194{,}7429 = -\ Ws$$

$$-\ Ws = 30 + \frac{11{,}7436}{64{,}3440} + 194{,}7429 =$$

- Ws = 224,92539 lbf.ft/lbm

Dengan: Capacity = 136,0289 gal/menit

Dari Fig 14.36, Hal. 520, Petters & Timmerhause, didapatkan:

Efisiensi pompa (η) = 40%

- Ws = - η Wp

224,9254 = - 40% Wp

Wp = 562,31349 ft.lb/lbm

mass flow rate (m) = Q x ρ

= 0,3031 x 86,4240

= 26,1929 lbm/s

$$WHp = Wp \times m \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

$$WHp = 562,31349 \times 26,1929 \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

WHp = 26,7793 hp

$$BHp = \frac{WHp}{\eta} = \frac{}{40\%}$$

= 66,9483 Hp = 70 Hp

Dari Fig 14.38 Hal. 521, Petters & Timmerhause, didapatkan:

Spesifikasi Pompa Sentrifugal = 89%

$$= \frac{\text{Pump horsepower}}{\text{Efisiensi motor}}$$

$$= \frac{66,9483}{89\%}$$

= 75,2228 Hp ≈ 75 Hp

Spesifikai Pompa Sentrifugal

Fungsi		:	Untuk mengalirkan keluaran centrefunge menuju UPL				
Kode alat		:	L-144				
Tipe		:	Centrifugal pump				
kapasitaas		:	136,0289 gpm				
Suhu Operasi		:	303,150 K				
Tekanan Operasi		:	1 atm				
Efisiensi Pompa		:	89%				
ΔP		:	30 lb/ft²				
Dimensi	NPS	:	4 in	OD :	4,5000	A :	0,0884
	Sch	:	80	ID :	4,0260		

25. Storage CHO2Na (F-145)

Fungsi : Menyimpan CHO2Na selama 7 hari

Tipe : Bejana tegak dengan tutup atas standart dishes dan tutup bawah flat (datar)

Direncanakan :

Suhu : 30 ˚C = 303,15 K

Tekanan Operasi	:	1	atm	=	14,7	psia	
Rate masuk	:	44003,8030	kg/jam	=	97010,78407	lb/jam	
				=	2328258,818	lb/hari	
Densitas	:	1,385	gr/cm^3	=	86,4627	lb/ft^3	
Waktu tinggal	:	7	hari	=	168	jam	
Bahan konstruksi	:	Stainless steel SA 240 Grade M Type 316					
Pengelasan	:	Double welded butt joint	E	=	0,8		
Faktor korosi	:	1/16	in				
Allowable stress	:	18750					
Volume kosong	:	20%	volume total				
Jumlah Tangki	:	1	buah				

Perhitungan :

a. Menentukan Volume

Volume bahan baku : $\dfrac{m}{\rho} \times$ waktu tinggal

: $\dfrac{97010,7841}{86,4627} \times 168$ jam

: 188495,2348 ft^3

volume liquid : $\dfrac{188495,2348}{1} = 188495,2348$ ft^3

V_T : $V_L + V_{RK}$

: $188495,2348 + 0,2\ V_T$

: 235619,0435 ft^3

b. Menentukan Diameter

Diketahui : Ls = 1,5 di

$V_{tangki} = V_{silinder} + V_{tutup\ atas\ SD}$

$235619,0435 = \left(\dfrac{\pi}{4} \times di^2 \times Ls\right) + 0,0847\ di^3$

$235619,0435 = 1,1775\ di^3 + 0,0847\ di^3$

$235619,0435 = 1,2622\ di^3$

$di^3 = 186673,3033$

di = 57,1515 ft

= 685,8176 in

c. Menentukan tinggi tangki yang terisi bahan

$$V_{tangki} = V_{silinder} + V_{tutup\ atas\ SD}$$

$$188495{,}2348 = \left(\frac{\pi}{4} \times di^2 \times Lls\right) + 0{,}0847\ di^3$$

$$188495{,}2348 = \left(\frac{\pi}{4} \times 57{,}1515^2 \times Lls\right) + 0{,}0847 \times 57{,}1515$$

$$188495{,}2348 = 2564{,}0380\ Lls + 15811{,}229$$

$$172684{,}0060 = 2564{,}0380\ Lls$$

$$Lls = 67{,}3485\ ft$$

$$= 808{,}1815\ in$$

$$Ls = 1{,}5 \times di$$

$$= 1{,}5 \times 685{,}8176$$

$$= 1028{,}7265\ in$$

$$= 85{,}7272\ ft$$

d. Menghitung tebal silinder

$$P_{hidrostatik} = \frac{\rho\ (H-1)}{144}$$ (Brownell dan Young pers. 3.17 Hal 46)

$$= \frac{86{,}4627 \times (85{,}7272 - 1)}{144}$$

$$= 50{,}8732\ psia$$

$$Pi = P_{atm} + P_{hidrostatik}$$

$$= 14{,}6959 + 50{,}8732$$

$$= 65{,}5691\ psia$$

$$= 50{,}8691\ psig$$

tebal silinder (ts)

$$= \frac{Pi.di}{2(f.E - 0{,}6Pi)} + C$$

$$= \frac{50{,}8691 \times 685{,}8176}{2 \times [(18750 \times 0{,}8000) - (0{,}6 \times 50{,}869)]} + \frac{1}{16}$$

$$= 1{,}2278 \times \frac{1}{16}$$

$$= \frac{1{,}2278}{16} \approx \frac{3}{16}$$

Standarisasi do

$$do = di + 2\ ts$$

$$= 685{,}818 + \left(2 \times \frac{3}{16}\right)$$

= 686,193 in

Standarisasi dengan Tabel 5.7, Brownell and Young, hal 89

do = 240

icr = 14 7/16

r = 180

ts = 1,1250

maka :

di_{baru} = do - ts

= 686,193 - (2 × 1,1250)

= 683,9426 in

= 56,9952 ft

Cek hubungan Ls dengan di:

Volume tangki = $\left(\frac{\pi}{4} \times di^2 \times Ls\right) + 0{,}0847\ di^3$

$235619{,}0435 = \left(\frac{3{,}14}{4} \times 56{,}9952^2 \times Ls\right) + 0{,}0847 \times 56{,}995$

235619,0435 = 2550,0372 Ls + 15681,9011

219937,1424 = 2550,0372 Ls

Ls = 86,2486 ft

$\frac{Ls}{di} = \frac{86{,}2486}{56{,}9952} = 1{,}5 < 1{,}5$ (memenuhi)

e. Menghitung tinggi silinder

Tinggi silinder (Ls) = 1.5 di

= 1,5 × 683,9426

= 1025,914 in

= 85,4928 ft

f. Menghitung tutup atas silinder (standar dished)

$tha = \frac{0{,}8850 \times Pi \times r}{f.\,E - 0.1.\,Pi} + C$

$= \frac{0{,}8850 \times 50{,}8691 \times 180}{[(18750 \times 0{,}8)-(0{,}1 \times 50{,}8691)]} + \frac{1}{16}$

$= \frac{8103{,}4523}{14994{,}9131} + \frac{1}{16}$

$$= 0{,}6029 \times \frac{16}{16}$$

$$= \frac{9{,}6466}{16} \approx \frac{3}{16}$$

Tinggi tutup atas (ha) = 0,169 x di baru
= 0,169 x 683,94
= 115,5863 in

g. Menghitung tinggi storage

Tinggi storage (H) = tinggi silinder + tinggi tutup atas
= 1025,914 + 115,5863
= 1141,5003 in
= 95,1250 ft

Spesifikasi alat :

Nama alat	:	Storage CHO2Na (F-145)
Fungsi	:	Menampung CHO2Na
Type	:	Tangki silinder vertikal, tutup atas standar dished tutup bagian bawah flat (dasar)
Bahan konstruksi	:	Stainless steel SA 240 Grade M Type 316
Volume tangki	:	235619,0435 ft^3
Diameter dalam (di)	:	683,9426 in
Diameter luar (do)	:	240 in
Tebal silinder (ts)	:	1,1250 in
Tinggi silinder (Ls)	:	1025,9140 in
Tebal tutup atas (tha)	:	3/16 in
Tinggi tutup atas (ha)	:	115,5863 in
Tinggi Storage (H)	:	1141,5003 in

26. Filter Udara (H-151)

Fungsi : Menyaring debu yang tersuspensi dalam udara proses

Tipe : *Dry Filter*

Dasar perhitungan:

Udara yang dibutuhkan = 67,0953 kg/jam = 147,9184 lb/jam

Suhu udara masuk = 120 °C = 248 °F

ρ udara pada 30 ºC = 0,0729 lb/ft^3

(Geankoplis, App. 3-3, page 866)

Perhitungan:

$$\text{Rate volume udara} = \frac{\text{Udara yang dibutuhkan}}{\rho \text{ udara pada 30 ºC}}$$

$$= \frac{147{,}9184}{0{,}0729}$$

$= 2029{,}2815 \; ft^3/jam$

$= 33{,}82135905 \; ft^3/menit$

Kadar debu dalam udara pada lingkungan industri (0,1 – 2 gram / 1000 ft^3)

(Perry's 7th ed, tabel 17-8, hal 17-48)

$$\text{Kadar debu dalam udara panas} = \frac{1 \text{ gram}}{1000 \; ft^3} \times \text{rate volume udara}$$

$$= \frac{1 \text{ gram}}{1000 \; ft^3} \times 33{,}82135905$$

$= 0{,}0338$ gram/menit

Ukuran *dry filter* = 24 × 24 inch

Kapasitas 1 filter = 1000 $ft^3/menit$ *(Perry's 7th ed, tabel 17-9, hal 17-50)*

$$\text{Jumlah filter yang dibutuhkan (N)} = \frac{\text{Rate volume udara}}{\text{Kapasitas 1 filter}}$$

$$= \frac{33{,}82135905 \; ft^3/menit}{1000 \; ft^3/menit}$$

$= 0{,}0338 = 1$ buah

Spesifikasi Peralatan:

Nama	:	Filter Udara (H-151)
Fungsi	:	Menyaring debu tersuspensi dalam udara proses
Tipe	:	*Dry Filter*
Bahan Konstruksi	:	*Carbon Steel*
Kapasitas	:	1000 $ft^3/menit$
Rate Volume Udara	:	33,82135905 $ft^3/menit$
Ukuran	:	24 × 24 inch
Jumlah	:	1 buah

27. Blower (G-152 A-B)

Fungsi : Menghembuskan udara menuju Heater Udara (E-153)

Tipe : *Centrifugal Blower*

Dasar perhitungan:

- Rate udara = 67,0953 kg/jam = 147,9184 lb/jam
- Suhu udara masuk = 30 °C = 86 °F
- ρ udara pada 30 ºC = 0,0729 lb/ft³ *(Geankoplis, App. 3-3, hal 866)*
- Rate volume udara (Q) $= \dfrac{\text{Rate udara}}{\rho \text{ udara}}$

$$= \frac{147{,}9184}{0{,}0729}$$

= 2029,2815 ft³/jam

= 33,8214 ft³/menit

Perhitungan:

Hp = 1,57 × 1,0E-03 QP *(Perry's 7th ed, hal 10-46)*

Maka :

Hp = 1,57 × 1,0E-03 (33,8214 × 1)

= 0,0531 Hp

η motor = 88 % *(Peters and Timmerhaus, fig. 14-38, hal. 521)*

Sehingga:

$$\text{Daya motor} = \frac{\text{power blower}}{\eta \text{ motor}} = \frac{0{,}0531}{88\%} = 0{,}0603 \approx 1 \text{ Hp}$$

Spesifikasi Peralatan:

Nama	:	Blower (G-152A-B)
Fungsi	:	Menghembuskan udara menuju Heater Udara (E-153)
Tipe	:	*Centrifugal Blower*
Kapasitas	:	67,0953 kg/jam
Power motor	:	1 Hp
Bahan	:	*Carbon steel*
Jumlah	:	1 buah

29. Heater (E-153)

Fungsi : Untuk memanaskan udara sebelum masuk Rotary dryer

Tipe : Double pipe Heat exchanger

Direncanakan:

- faktor kekotoran gabungan minimum (Rd) = 0,0025 jam. Ft² (*kern* , Halaman 107)
- penurunan tekanan aliran maksimum (Δp) = 10 psi
- ΔP maksimum steam = 2 psi
- Digunakan pipa ukuran 1 in
- pipa : Steam
- Anulus : udara

Dasar perencanaan:

Dari Appendix B dan C didapatkan data sebagai berikut:

- Masssa bahan masuk (M) = 67,095342 kg/jam
  = 147,91839 lb/jam
  =
- Suhu bahan masuk (t_1) = 30 °C = 86 °F = 303,15 K
- Suhu bahan keluar (t_2) = 120 °C = 248 °F = 393,2 K
- Kebutuhan steam (m) = 14,215469 kg/jam
  = 31,339 lb/jam
- Panas yang dibawah steam = 651,75971 kj/jam
  = 617,74893 btu/jam
- steam masuk pada suhu (T_1) = 130 °C = 266 °F
- Steam keluar pada suhu (T_2) = 130 °C = 266 °F
- Beban Panas = 30907,1315 = 12256,953 Btu/jam
- Pipa = Steam
- Anulus = udara

Perhitungan

A. Menghitung Δt

$\Delta t_1 = T_1 - t_2 = 266 - 248$ °F $= 18$ °F

$\Delta t_2 = T_2 - t_1 = 266 - 86$ °F $= 180$ °F

$$\Delta T_{LM} = \frac{\Delta t_1 - \Delta t_2}{\ln \Delta t_1 / \Delta t2}$$

$$= \frac{18 - 180}{\ln 126}$$

$$\frac{}{180}$$

= 454,1951 °F

B. Menghitung suhu Kalorik (T_c dan t_c)

Tc = (T_1 + T_2)/2 = 266 °F = 130 °C

tc = (t1 + t2)/2 = 210 °F = 99 °C

$$= \frac{130 - 99}{\ln \frac{130}{99}}$$

= 113,7362 °F

C. Trial U_D

- Asumsi UD = 50,0000 Btu/jam.ft².°F

$$A = \frac{Q}{U_d \cdot \Delta t}$$

$$= \frac{12.256,9525 \text{ Btu/jam}}{50,0000 \text{ Btu/jam.ft}^2.°F \times 113,74 °F}$$

= 2,1553 ft²

D Trial ukuran double pipe:

dicoba ukuran double pipe 2 1/2 'x 1 1/4" IPS sec. 40 dengan aliran steam

Bagian pipa anulus (Kern tabel 6.2 ha 110)

a_{an}	=	3	in^2	=	0,0183	ft^2
de	=	2	in	=	0,1683	ft
de'	=	1	in	=	0,0675	ft

Bagian Pipa (Kern, tabel 11 hal 844)

ap	=	2	in^2	=	0,0104	ft^2
di	=	1	in	=	0,1150	ft
do	=	2	in	=	0,1383	ft
a"	=	0,435	ft^2/ft	=		

Evaluasi Perpindahan Panas	
Annulus, udara	*Hot fluida,inner pipe ,steam*
1. Menghitung Nre anulus Gaan = $\frac{m}{a_{an}}$ = $\frac{147,918 \text{ lb/jam}}{}$	1. Menghitung N_{Re} pipa $G_p = \frac{m}{a_p}$ = $\frac{12256,9525 \text{ lb/jam}}{0,0104 \text{ ft}^2}$

$$= \frac{}{0{,}0183 \ ft^2}$$

$= 8098{,}9537$ lb/jam.ft²

ada tc $= 86$ °F

$\mu = 0{,}9498$ Cp

(fig.24"kern",hal 834)

$$N_{Re} = \frac{G_{AA} \times di}{\mu \times 2{,}42}$$

$$= \frac{8098{,}9537 \times 0{,}1683}{0{,}9498 \times 2{,}42}$$

$= 593{,}1322081$

2. JH = 23 (fig 24" kern" hal 834
3. Menghitung harga koefisien film

Cp = 0,143 Btu/lb°F

k = 0,273 Btu/jam.ft²°F/ft

$$\left(\frac{Cp\ \mu}{k}\right)^{1/3} = \left(\frac{0{,}14 \times 0{,}9}{0{,}2730}\right)^{1/3}$$

$= 0{,}7924$

$$ho = \frac{Jh \times K \times}{De} \left(\frac{Cp.\mu}{k}\right)^{1/3}$$

$= 29{,}55667287$

$$\frac{ho}{\varphi s} = 108 \ \text{Btu/jam ft}^2\ {}^oF$$

$= 1176667{,}4442$ lb/jam ft2

μ pada T_c = 266 °F

= 0,98 cp

(Geankoplis, tabel A.2-4, hal 855)

$$NRe_p = \frac{G_p \times di}{\mu \times 2{,}42}$$

$$= \frac{1176667{,}4442 \quad 0{,}1150}{0{,}9800 \times 2{,}42}$$

$= 57057{,}1581$

2. JH = 18 (fig 24" kern" hal 834
3. Menghitung harga koefisien film

Cp = 0,234 Btu/lb°F

k = 0,122 Btu/jam.ft²°F/ft

3. Harga koefisien perpindahan panas untuk steam didapatkan

hi = 1,0792 Btu/jam.ft²°F

hio = hi x (ID/OD)

$= 1{,}2982051$ Btu/jam ft^2 ^{o}F

E. Menghitung clean overall coefficient (U_C)

$$U_C = \frac{ho \times hio}{ho + hio}$$

$$= \frac{29{,}6 \times 1{,}2982}{29{,}6 + 1{,}2982}$$

$= 1{,}2436$ Btu/jam ft^2°F

F. Menghitung design overall coefficiet (U_D)

$$Rd = \frac{U_C - U_D}{U_C \times U_D}$$

$$\frac{1}{U_D} = \frac{1}{U_C} + Rd$$

$$\frac{1}{U_D} = \frac{1}{1{,}244} + 0{,}0010$$

$$\frac{1}{U_D} = 0{,}8051$$

U_D = 1,242 Btu/jam ft^2°F

G. Menghitung luas permukaan (A) yang diperlukan

$$A = \frac{Q}{U_D \times \Delta t} = \frac{12256{,}9525}{1{,}2420 \times 180{,}0000} = 54{,}824504 \text{ ft}^2$$

$$L = \frac{A}{a''} = \frac{54{,}82}{0{,}4350} = 256{,}32 \text{ ft}$$

H. Menghitung dirt factor (Rd) yang terpakai

$$Rd = \frac{U_C - U_D}{U_C \times U_D}$$

$$= \frac{1{,}2436 - 1{,}2420}{1{,}2436 \times 1{,}2420}$$

= 0,001 jam ft^2 °F/Btu

I. Mencari panjang ekonomis

dengan mencari over design yang terkecil dari panjang pipa standart

L (ft)	n	n_{pakai}	L_{baru}	A_{baru}	$U_{D\ baru}$	Rd_{baru}	$Rd_{over\ desain}$
12	24	11	256,32	111,50	0,0090	-1000	-250001
17	34	8	256,32	111,50	0,0090	-1000	-250001
20	40	6	256,32	111,50	0,0090	-1000	-250001

Karena over desainnya sama, maka dipilih DPHE dengan jumlah hairpin paling sedikit.

L = 20 ft dan n = 6 buah

Evaluasi Δp	
Annulus	Inner
1. Pada NRe_{an} = 593,1322	1. Pada NRe_p = 57057,1581
$f = 0{,}0035 + \frac{0{,}264}{NRe^{0{,}42}}$	$f = 0{,}0035 + \frac{0{,}264}{NRe^{0{,}42}}$

Annulus	Pipe
$= 0{,}0035 + \frac{0{,}264}{14{,}6125}$	$= 0{,}0035 + \frac{0{,}264}{99{,}46}$
$= 0{,}0216$	$= 0{,}0062$
2. $\rho = 56{,}8958$ lb/ft^3	2. $\rho = 993{,}622$ kg/m^3
$\Delta P_1 = \frac{. G_{an}^2 . L}{2 . g . \rho^2 . do} \times \frac{\rho}{144}$	$= 62{,}0020$ lb/ft^3
$= 0{,}2636 \times 0{,}3951$	$\Delta P_p = \frac{. G_p^2 . L}{2 . g . \rho^2 . do} \times \frac{\rho}{144}$
$= 0{,}1041$ Psi	$= 0{,}964 \times 0{,}4306$
	$= 0{,}4151$ Psi
3. $V = \frac{G_{an}}{3600 \times \rho}$	$\Delta P_p < \Delta P_{allow}$
$= \frac{593{,}1322}{3600 \times 56{,}896}$	$0{,}4151 < 2$
$= 0{,}0029$	Memadai
$\Delta P_n = n \times \left(\frac{V^2}{2 . gc}\right) \times \left(\frac{\rho}{144}\right)$	
$= 6 \times 1E\text{-}07 \times 0{,}3951$	
$= 0{,}0003$ Psi	
$\Delta P_{an} = \Delta P_1 + \Delta P_n$	
$= 0{,}1041 + 0{,}0003$	
$= 0{,}1045$ Psi	
$\Delta P_{an} < \Delta P_{allow}$	
$0{,}1045 < 10$	
Memadai	

Spesifikasi alat :

Nama alat	:	Heater(E-153)
Fungsi	:	Menaikkan suhu udara sebelum masuk ke rotary dryer
Tipe	:	Double pipe heat exchanger
Bahan konstruksi	:	Carbon steel
Media pemanas	:	Steam
Kapasitas	:	67,09534166 kg/jam
Rate steam	:	14,2155 kg/jam

Ukuran	:	3" × 2" IPS sch. 40							
Dimensi	:	Bagian anulus				Bagian pipa			
		a_{an}	=	3	in^2	a_p	=	1,5	in^2
		de	=	2	in	di	=	1,4	in
		de'	=	1	in	do	=	1,7	in
						a"	=	0,4	ft^2/ft
Jumlah hair pin	:	6	buah						
Jumlah	:	1							

30. Cyclone (H-154)

Fungsi : Memisahkan debu atau partikel pentaeritritol yang terikut udara dari Rotary Dryer (B-150)

Tipe : *Duclone Collector*

Dasar perhitungan:

- Rate udara = 67,09534166 kg/jam = 147,9184 lb/jam
- ρ udara = 0,0592 lb/ft^3 *(Geankoplis, App. A-3-3, hal. 866)*

Perhitungan:

Rate volumetrik udara $= \dfrac{\text{rate udara}}{\rho\ \text{udara}} = \dfrac{147{,}9184\ \text{lb/jam}}{0{,}0592\ \text{lb/ft}^3}$

$= 2498{,}6215\ \text{ft}^3\text{/jam} = 0{,}6941\ \text{ft}^3\text{/detik}$

Kecepatan udara cyclone = 50 - 90 ft/detik *(Perry's 7th ed, hal 17-30)*

Luas aliran (Ac) $= \dfrac{\text{rate volumetrik udara}}{\text{kecepatan udara}}$

$= \dfrac{0{,}6941\ \text{ft}^3\text{/detik}}{50\ \text{ft/detik}} = 0{,}0139\ \text{ft}^2$

Dari Perry's 7th ed hal. 17-27 didapatkan:

$$Bc = Jc = \frac{Dc}{4}$$

$$Hc = De = \frac{Dc}{2}$$

$$Ac = Bc \times Hc$$

$$Sc = \frac{Dc}{8}$$

$$Zc = Lc = 2\ Dc$$

Dimana :

Ac = Luas aliran pada cyclone (ft^2)
Bc = Lebar inlet dust (ft)
Hc = Tinggi inlet dust (ft)
Jc = arbitrary (ft)
Dc = diameter keluaran pada cyclone (ft)
Lc = panjang penampungan cyclone pada arah aliran gas (ft)
Zc = panjang penampungan cyclone pada arah aliran debu (ft)

Maka :

$Ac = Bc \times Hc$

$0{,}0139 = Bc \times Dc/2$

$0{,}0139 = Bc \times 4\ Bc/2$

$0{,}0139 = 2\ Bc^2$

Bc = 0,0833 ft

Sehinggga:

Dc = 4 Bc = 0,3332 ft
Jc = Bc = 0,0833 ft
Hc = De = Dc / 2 = 0,1666 ft
Zc = Lc = 2 Dc = 0,6665 ft
Sc = Dc/8 = 0,0416552 ft

Diameter pada cyclone

$$Dpc = \sqrt{\frac{9 \times \mu \times Bc}{2 \times \pi \times Ne \times Vc \times (\rho s - \rho)}}$$

Dimana :

Bc = Lebar inlet (ft) *(Geankoplis, App A.3-3)*
μ = Viskositas gas (0,00001464 lb/ft.s)
Ne = 3,5
Vc = Kecepatan gas masuk cyclone (50 ft/s)
ρs = Densitas bahan (64,3008 lb/ft^3)
ρ = densitas gas (0,0592 lb/ft^3)

Maka :

$$Dp\ min = \sqrt{\frac{9 \times 0{,}00001464 \times 0{,}1509}{2 \times 3{,}14 \times 3{,}5 \times 50 \times (64{,}3008 - 0{,}0592)}}$$

= 0,00001247 ft

Diketahui diameter partikel = 325 mesh = 0,044 mm = 0,000144 ft

Dp min lebih kecil daripada diameter partikel, maka ukuran cyclone memenuhi.

Spesifikasi alat :

Nama Alat	:	Cyclone (H-154)
Fungsi	:	Memisahkan debu atau partikel pentaeritritol yang terikut udara dari Rotary Dryer (B-150)
Tipe	:	*Duclone Collector*
Dimensi	:	Dc = 0,3332 ft; Sc = 0,0417 ft
		De = 0,1666 ft; Zc = 0,6665 ft
		Hc = 0,1666 ft; Jc = 0,0833 ft
		Lc = 0,6665 ft; Bc = 0,0833 ft
Bahan konstruksi	:	*Carbon Steel*
Jumlah	:	1 buah

31. Belt Conveyor (J-155)

Fungsi : Mengangkut cake pentaeritritol menuju bucket elevator (J-156)

Tipe : *Horizontal cooling conveyor*

Dasar perhitungan:

- Rate bahan : 8852,5458 kg/jam = 19516,3225 lb/jam
  = 8,8525 ton/jam
- ρ produk : 1385,00 kg/cm^3 = 86,4240 lb/ft^3
- Faktor keamanan : 20 %
- Kapasitas : 120 % × 8852,5458 = 10623,0550 kg/jam
  = 23419,5870 lb/jam

$$\text{Rate Volumetrik} = \frac{\text{massa bahan}}{\rho \text{ produk}}$$

$$= \frac{23419{,}5870}{86{,}4240}$$

$$= 270{,}9848 \ ft^3/j \quad 4{,}5164 \ ft^3/\text{menit}$$

Berdasarkan Perry edisi 7, hal 21-8, tabel 21-6, dipilih belt conveyor dengan spesifikasi sebagai berikut:

- Kapasitas = 15 ton/jam
- Panjang conveyor = 10 ft
- Diameter Flight = 10 in

- Diameter Pipa = 2,5 in
- Diameter Shaft = 2 in

Perhitungan :

a. Perhitungan power :

$$Hp = \frac{C \times L \times W \times F}{3300}$$

Dimana :

C = Kapasitas belt conveyor

L = panjang conveyor

W = densitas bahan

F = material faktor

$$Hp = \frac{4{,}5164 \times 10 \times 86{,}4240 \times 2{,}5}{3300}$$

$= 2{,}9570$ Hp *(Peter & Timmerhauss fig. 14.3*

b. Effisiensi motor : 84%

$$= \frac{2{,}9570}{84\%} = 3{,}5203 \text{ Hp} \approx 4 \text{ Hp}$$

Spesifikasi alat :

Nama Alat	:	Belt Conveyor (J-155)
Fungsi	:	Mengangkut cake pentaeritritol menuju bucket elevator (J-156
Tipe	:	*Horizontal belt conveyor*
Kapasitas	:	10623,0550 kg/jam
Bahan	:	*Carbon steel*
Panjang	:	10 ft
Daya motor	:	4 Hp
Jumlah	:	1 buah

32. Bucket Elevator (J-156)

Fungsi : Mengangkut cake Chitosan menuju bin produk (F-157)

Kapasitas : 8852,5458 kg/jam = 8,8525 ton/jam = 212,4611 ton/hari

Tipe : Centrifugal Discharge Bucket Elevator

Pemilihan alat :

Dari Perry ed. 7, tabel 21-8 didapatkan :

Kapasitas	:	14	ton/jam
Tinggi Elevasi	:	25	ft
Kecepatan Bucket	:	225	ft/min
Bucket Spasing	:	14	in
Ukuran Bucket	:	6 x 4 x 4 1/4	in

Perhitungan :

a. Kecepatan Bucket : $\frac{8,8525458}{14} \times 225 = 142,2731$ ft/min

b. Power dihitung dengan rumus :

Power (P) $= \frac{Q \times 2 \times h}{1000}$

P : Jarak tempuh bucket
h : tinggi elevasi
Q : Kapasitas (ton/hari)

Power (P) $= \frac{212,4611 \times 2 \times 25}{1000} = 10,6231$ hp

Efisiensi Motor = 82%

hp motor $= \frac{10,6231 \text{ hp}}{82\%}$

$= 12,954945$ hp ≈ 13 hp

Spesifikasi Alat	:		
Nama	:	Bucket Elevator (J-156)	
Fungsi	:	Mengangkut pentaeritritol menuju bin produk (F-157)	
Tipe	:	Centrifugal Discharge Bucket Elevator	
Kapasitas	:	8,8525	ton/jam
Tinggi Elevasi	:	25	ft
Kecepatan Bucket	:	225	ft/min
Bucket Spasing	:	14	in
Ukuran Bucket	:	6 x 4 x 4 1/4	in
Daya Motor	:	13	hp
Jumlah	:	1	buah

33. Bin Produk Pentaeritritol (F-157)

Fungsi : Untuk menampung produk Chitosan sebelum dimasukkan ke dalam Packing Machine (J-128)

Tipe : Tangki silinder dengan tutup bawah conical (60°) dan tutup bagian atas flat (dasar)

Dasar perhitungan:

- Suhu : 30 °C
- Rate massa masuk : 8852,55 kg/jam = 19516,3225 lb/jam
- Densitas : 1385,00 kg/cm^3 = 86,4240 lb/ft^3
- Waktu tinggal : 1 jam
- Bahan konstruksi : HAS SA 240 Grade M Type 316
- Pengelasan : Double welded butt joint, E = 0,8
- Faktor korosi : 1/16
- Allowable stress : 18750

Perhitungan :

a. Menentukan Volume

Massa bahan masuk = 19516,3225 lb/jam × 1 jam

= 19516,3225 lb

$$\text{Volume bahan} = \frac{\text{massa}}{\rho} = \frac{19516{,}3225}{86{,}4240} = 225{,}8206 \quad ft^3$$

Volume bahan pengisi adalah 80% dari volume tangki, maka:

$$\text{Volume tangki} = \frac{\text{volume bahan}}{\text{\% volume isi}} = \frac{225{,}8206}{80\%} = 282{,}2758$$

b. Menentukan Diameter

Diketahui : Ls = 1,5 di

$V_{tangki} = V_{silinder} + V_{conical}$

$$282{,}2758 = \left(\frac{\pi}{4} \times di^2 \times Ls\right) + \frac{\pi\, di^3}{24 \text{ tg } ½\, \alpha}$$

$$282{,}2758 = \left(\frac{\pi}{4} \times di^2 \times 1{,}5\, di\right) + \frac{\pi\, di^3}{24 \text{ tg } 30}$$

$$282{,}2758 = 1{,}1775 \quad di^3 + 0{,}2266 \quad di^3$$

$$282{,}2758 = 1{,}4041 \quad di^3$$

$$di^3 = 201{,}0382$$

$$di = 5{,}8581 \quad ft$$

$= 70{,}2976$ in

c. Menentukan tinggi tangki yang terisi bahan

$$V_{tangki} = V_{silinder} + V_{conical}$$

$$282{,}2758 = \left(\frac{\pi}{4} \times di^2 \times H\right) + \frac{\pi\, di^3}{24 \text{ tg } ½\, \alpha}$$

$$282{,}2758 = \left(\frac{\pi}{4} \times 5{,}8581^2 \times H\right) + \frac{\pi\,(5{,}8581)^3}{24 \text{ tg } 30}$$

$$282{,}2758 = 26{,}9394\ H + 45{,}5533$$

$$26{,}9394\ H = 236{,}7225$$

$$H = 8{,}7872 \text{ ft}$$

d. Menghitung tebal silinder

$$P_{hidrostatik} = \frac{\rho\,(H-1)}{144}$$

(Brownell dan Young pers. 3.17 Hal 46)

$$= \frac{86{,}4240 \times (8{,}7872 - 1)}{144}$$

$$= 4{,}6736 \text{ psia}$$

$$Pi = P_{atm} + P_{hidrostatik}$$

$$= 14{,}6959 + 4{,}6736$$

$$= 19{,}3695 \text{ psia}$$

$$= 4{,}6695 \text{ psig}$$

tebal silinder (ts)

$$= \frac{Pi.di}{2(f.E - 0{,}6Pi)} + C$$

$$= \frac{4{,}6695 \times 70{,}2976}{2 \times [(18750 \times 0{,}8) - (0{,}6 \times 4{,}6695)]}$$

$$= 0{,}0109 + \frac{1}{16}$$

$$= \frac{1{,}1751}{16} \approx \frac{3}{16}$$

Standarisasi do

$$do = di + 2\ ts$$

$$= 70{,}2976 + \left(2 \times \frac{3}{16}\right)$$

$$= 70{,}6726 \text{ in}$$

Standarisasi dengan Tabel 5.7, Brownell and Young, hal 89

do = 22

icr = 1 3/8

r = 21

ts = 3/16

maka :

di_{baru} = do - ts

$= 22 - (2 \times \frac{3}{16})$

= 21,6250 in

= 1,8021 ft

Cek hubungan Ls dengan di:

$$\text{Volume tangki} = (\frac{\pi}{4} \times di^2 \times Ls) + \frac{\pi\, di^3}{24 \text{ tg } ½\, \alpha}$$

$$282{,}2758 = (\frac{\pi}{4} \times 1{,}8021^2 \times Ls) + \frac{\pi \times 1{,}8021^3}{24 \text{ tg } 30}$$

282,2758 = 2,5493 Ls + 1,3261

2,5493 Ls = 280,9497

Ls = 110,2070 ft

$$\frac{Ls}{di} = \frac{110{,}2070}{1{,}8021} = 61{,}1553 < 1{,}5 \quad \text{(memenuhi)}$$

e. Menghitung tinggi silinder

Tinggi silinder (Ls) = 1,5 di

$= 1{,}5 \times 21{,}6250$

= 32,4375 in

= 2,7031 ft

f. Menghitung tutup bawah silinder

$$thb = \frac{Pi.di}{2 \cos ½\, \alpha\, (fE - 0{,}6Pi)} + C$$

$$= \frac{4{,}6695 \times 21{,}6250}{2 \times \cos 30 \times [(18750 \times 0{,}8) - (0{,}6 \times 4{,}670)]}$$

$$= 0{,}0039 + \frac{1}{16}$$

$$= \frac{1{,}0622}{} \sim \frac{3}{}$$

$$- \frac{}{16} \sim \frac{}{16}$$

Tinggi tutup bawah (hb) $= \dfrac{\frac{1}{2}\ di}{tg\ \frac{1}{2}\ \alpha}$

$= \dfrac{\frac{1}{2} \times 21{,}6250}{tg\ 30}$

= 18,7262 in

g. Menghitung tinggi storage

Tinggi storage (H) = tinggi silinder + tinggi tutup bawah

= 51,1637 in

= 4,2636 ft

Spesifikasi alat :

Nama alat	:	Bin Produk Pentaeritritol (F-157)
Fungsi	:	Menampung produk Pentaeritritol sebelum masuk ke Packing Machine (J-158)
Type	:	Tangki silinder dengan tutup bawah berbentuk conical (60°) dan tutup bagian atas flat (dasar)
Bahan konstruksi	:	Stainless steel
Volume tangki	:	282,2758 ft^3
Diameter dalam (di)	:	21,6250 in
Diameter luar (do)	:	22 in
Tebal silinder (ts)	:	3/16 in
Tinggi silinder (Ls)	:	32,4375 in
Tebal tutup bawah (thb)	:	3/16 in
Tinggi tutup bawah (hb)	:	18,7262 in
Tinggi silo (H)	:	51,1637 in

33. Packing Machine (J-128)

Fungsi : Pengemas produk Pentaeritritol dari Bin produk (F-158) menjadi bentuk *paper bag* ukuran 25 kg

Dasar perhitungan:

Kapasitas bahan = 8852,5458 kg/jam = 19516,3225 lb/jam

Kapasitas mesin = 19516,3225 lb/jam × 1 jam

= 19516,3225 lb

Densitas (ρ) = 1385,00 kg/cm^3 = 86,4628 lb/ft^3

Perhitungan:

$$\text{Volume mesin} = \frac{\text{Kapasitas mesin}}{\text{Densitas bahan}}$$

$$= \frac{19516{,}3225}{1385{,}0}$$

$$= 14{,}0912 \quad ft^3$$

Spesifikasi Alat:

Nama	:	Mesin pengemasan produk (J-158)
Fungsi	:	Untuk mengemas produk Pentaeritritol dari bin produk
Bahan konstruksi	:	*Carbon steel*
Kapasitas mesin	:	19516,3225 lb
Volume mesin	:	14,0912 ft^3
Jumlah	:	1 buah

35. Gudang Produk (F-159)

Fungsi	:	Menyimpan produk Pentaeritritol yang telah dikemas selama 7 hari
Tipe	:	Bangunan Gudang
Bahan	:	Beton

Dasar Perhitungan :

-	Suhu	:	30	°C			
-	Tekanan	:	1	atm			
-	Waktu tinggal	:	7	hari			
-	Kapasitas	:	8852,5458	kg/jam	=	19516,3225	lb/jam
					=	468391,7397	lb/hari
-	Densitas	:	1385,00	kg/cm^3	=	86,4240	lb/ft^3
-	Volume bahan	:	80%	volume gudang			

Perhitungan :

$$\text{Volume bahan} = \frac{\text{massa bahan} \times \text{waktu tinggal}}{\rho \text{ produk}}$$

$$= \frac{468391{,}7397 \text{ lb/hari} \times 7 \text{ hari}}{86{,}4240}$$

$$= 37937{,}8665 \quad ft^3$$

Volume ruang kosong = 20% volume gudang

Volume gudang = volume bahan + volume ruang kosong

Volume gudang = 37937,8665 + 0,20 volume gudang
0,8 Volume gudang = 37937,8665
Volume gudang = 47422,3332 ft^3

Ditetapkan : Panjang = 2 kali lebar
Tinggi = 40 ft
Maka : $V_{storage}$ = p × l × t
47422,3332 = 2 l × l × 40
1185,5583 = 2 l^2
l^2 = 592,7792
l = 24,3471 ft
p = 48,6941 ft

Spesifikasi alat :

Nama alat	:	Gudang produk (F-159)
Fungsi	:	Menyimpan produk Pentaeritritol yang telah dikemas selama 7 hari
Tipe	:	Bangunan Gudang
Bahan	:	Beton
Kapasitas	:	37937,8665 ft^3
Tinggi	:	40 ft
Lebar	:	24,3471 ft
Panjang	:	48,6941 ft
Jumlah	:	2 buah

36. Rotary Vacuum Filter (B-150)

Fungsi : Memisahkan cake dari filtratnya
Tipe : Rotary drum vacuum filter

Dasar Perhitungan :

- Kapasitas cake = 8595,88 kg/jam
  = 18950,4793 lb/jam
- ρ campuran = 86,4240 lb/ft^3
- Rate cake $= \dfrac{\text{kapasitas cake}}{\rho \text{ campuran}} = \dfrac{18950,4793}{86,4240}$
  = 219,2733 ft^3/jam
  = 3,6546 ft^3/menit
- Tebal cake = ¼ in *(Perry 7th ed, hal 18-*

$= 0,0208333$ ft

Jika, 1 menit terdapat ½ putaran maka untuk 1 jam $= 60 \times 0,5$
$= 30$ putaran

Perhitungan :

Jumlah bahan yang diputar $= \frac{\text{kapasitas cake}}{\text{banyak putaran}}$

$= \frac{18950,4793}{30}$

$= 631,6826$ lb/putaran

Volume bahan yang diputar $= \frac{\text{jumlah bahan yang diputar}}{\rho \text{ campuran}}$

$= \frac{631,6826}{86,4240}$

$= 7,3091$ ft^3/jam

Luas cake $= \frac{\text{volume cake}}{\text{tebal cake}}$

$= \frac{7,3091}{0,0208}$

$= 350,8373$ ft^2

$= 32,5945$ m^2

Diketahui : D $= 1$ m *(Ulrich, tabel 4-23b, hal 222)*
$= 3,2808$ ft

Luas drum $= 2 \pi D L$

$350,8373 = 2 \times 3,14 \times 3,2808 \times L$

$L = 17,0281$ ft

Power total $= A^{0,75}$ *(Ulrich, tabel 4-23b, hal 222)*
$= 13,6414$ kW
$= 18,2931$ Hp $\approx$ 21 Hp

Spesifikasi Alat :

Nama alat : Rotary Vacuum Filter (B-150)

Fungsi : Memisahkan cake dari filtratnya

Tipe	:	Rotary Drum Vacuum Filter	
Bahan	:	Stainless steel	
Kapasitas	:	18950,4793	lb/jam
Volume bahan putar	:	7,3091	ft^3/jam
Luas cake	:	350,8373	ft^2
Diameter drum	:	3,2808	ft
Daya	:	21	Hp
Jumlah	:	1	buah