APPENDIKS C
SPESIFIKASI PERALATAN

1. STORAGE C_2H_5OH (F-111)

Fungsi : Tempat penyimpanan etanol (C_2H_5OH)

Tipe : Silinder tegak tutup atas dan bawah berbentuk standard dished

A. Dasar perancangan

- Waktu tinggal : 3 hari
- MassaC_2H_5OH : 14631,1 kg/jam = 32255,6169 lb/jam

Komponen	Massa kg/jam	Densitas (ρ) kg/m^3	xi	xi.ρi
C_2H_5OH	14631,0518	555,00	0,995	552,225
H_2O	73,5229	995,95	0,005	4,980
Total	14704,5747	1550,95	1,000	557,205

(Perry's 8th, tabel 2-112 dan 2-30)

ρ campuran $= \frac{\Sigma xi.\rho i}{\Sigma xi}$

$= \frac{557,2047}{1,000} =$ 557,2 kg/m = 34,77 lb/ft^3

B. Menentukan volume liquida

Kapasitas C_2H_5OH $= \frac{\text{Kapasitas } C_2H_5OH}{\text{Jumlah storage yang digunakan}}$

$= \frac{32255,61685}{3}$

$=$ 10751,87228 lb/jam

Rate volumetrik $= \frac{\text{Kapasitas } C_2H_5OH \text{ pada storage}}{\rho \quad C_2H_5OH}$

$= \frac{10751,87228 \text{ lb/jam}}{34,76957578 \text{ lb/ft}^3}$

$=$ 309,2321964 ft^3/jam

Volume liquida $=$ Rate volumetrik x waktu tinggal

$=$ 309,2321964 x 3 hari x 24 jam

$=$ 22264,71814 ft^3

$=$ 630,0915234 m^3

C. Menentukan volume tangki

Rumus : $V_T = V_L + V_{RK}$

Dimana : V_T = Volume tangki

V_L = Volume liquida

V_{RK} = Volume ruang kosong

Untuk menentukan dimensi bejana, maka diasumsikan :

- Volume ruang kosong = 10% volume tangki
- Volume liquida = 90% volume tangki

Karena volume liquida 90% volume tangki maka, maka :

Volume tangki $= \frac{\text{Volume liquida}}{0,10}$

$= \frac{630,0915234}{10\%}$

$=$ 6300,915234 ft^3 = 178,3159 m^3

D. Menentukan diameter tangki (di)

Volume tangki $= V_{silinder} + V_{tutup}$

$6300,915234 = \left(\frac{\pi}{4} di^2 \times Ls\right) + 0,0847\ di^3$

$= \left(\frac{\pi}{4} di^2 \times 1,5\ di\right) + 0,0847\ di^3$

$6300,915234 = 1,2622\ di^3$

$di^3 = \frac{6300,915234}{1,2622}$

$di^3 = 4992,010168$

$di = 12,86715813$ ft

$= 154,4058976$ in

E. Menghitung tinggi liquida dalam tangki (L_{ls})

$V_{liquida} = \frac{\pi}{4} di^2 \times LIs$

$309,2321964 = \frac{3,14}{4} \times 12,86715813^2 \times LIs$

309,2321964 = 129,9675504 LIs

LIs = 2,379303107 ft

F. Menentukan tekanan design (P_{design}) = $\frac{\rho \, x \, (H-1)}{144}$ (Brownell pers 3,17 hal 46)

Tekanan hidrostatik (ρh)

$$= \frac{34,7696 \text{ lb/ft}^3 \text{ X } 2,3793 \text{ ft} - 1}{144}$$

$$= 0,3330 \text{ psia}$$

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

= 14,7 + 0,3330

= 15,0330 psia

= 29,7330 psig

G. Menghitung tebal tangki (ts)

Diketahui : Data didapatkan dari Brownell hal 342

- Bahan kontruksi yang dipilih : Hygh alloy steel SA - 240 Grade M Type 316
- f = 18750 psi
- E = 0,8 Double welded butt joint
- C = 1/16
- $Ts = \frac{Pi.di}{2(f.E - 0,6Pi)} + C$

$$= \frac{29,7330 \text{ x } 154,4059}{2 (18750 \text{ x } 0,8 -)(1 \text{ x } 29,733)} + \frac{1}{16} \text{ in}$$

$$= \frac{4590,9568}{29964,3204} + 1/16$$

= 0,1532 + 1/16 (Brownell & Young Table 5.7 hal 90)

= 0,213 in x $\frac{16}{16}$ = $\frac{3}{16}$

H. Menentukan harga di(baru), Ls, icr, dan r

Standarisasi do

do = di (lama) + 2 ts

= 154,4059 + 2 x 3/16

= 154,4059 + 0,3750

= 154,7809 in

dari tabel 5.7 (Brownell hal. 90) didapatkan:

do (baru) = 156 in

di = do (baru) - 2 ts

= 156 - 2 x 3/16

= 155,6250 in

Ls = 1,8 di

= 1,8 x 155,6250

= 280,1250 in

ha = 0,1690 di

= 0,1690 x 155,6250

= 26,3006 in

$$tha = \frac{0,885 \text{ x pi x di}}{(f \text{ x } E - 0.1pi)} + C$$

$$= \frac{0,8850 \text{ x } 29,733 \text{ x } 155,6250}{(18750 \text{ x } 0,8 - 0,1 \text{ x } 29,733)}$$

$$= \frac{4095,0759}{14997,027}$$

= 0,2731 = 2/7 in

Tinggi storage = Ls + ha

H = 280,13 + 26,30

= 306,43 in

2. ETHANOL PUMP (L-112)

- Fungsi : Mengalirkan ethanol dari tangki penyimpanan ke Reaktor
- tipe : Pompa centrifugal

Kondisi operasi:

- Suhu (T) : 30 ^oC
- Tekanan (P) : 1 atm

Komponen	Massa	xi	μ	μ	xi μ

Komponen	(kg/jam)	massa	(Cp)	(lbm/fts)	xi. μ
C_2H_5OH	14631,0518	0,9950	1,2	0,000806364	1,2
H_2O	73,5229	0,0050	0,87	0,000584614	3E-06
Total	14704,5747	1,0000	2,0700	0,001390978	1,2

(Geankoplis Figure A.3-4 Hal 876)

$$\mu \text{ campuran} = \frac{\sum xi.\mu}{\sum xi} = \frac{1,200002923}{1} = 1,200002923 \text{ kg/m .s}$$

Direncanakan

- Rate Liquid : 14704,57 kg/jam = 32423,5872 lb/jam
- Densitas Liquid : 34,77 lb/ft^3 51,743 kg/m^3
- Viskositas Liquid : 1,200002923 Cp

A. Menghitung rate volumetrik

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

$$= \frac{32423,59 \text{ lb/jam}}{34,77 \text{ lb/ft}^3}$$

$$= 932,5275 \text{ ft}^3\text{/jam}$$

$$= 0,25903543 \text{ ft}^3\text{/s}$$

$$= 111,903306 \text{ gal/menit}$$

B. Menentukan dimensi pipa

ID optimal $= 3,9\ Q^{0,45}\ \rho^{0,13}$ (Peter, pers. 15, hal 496)

$$= 3,9 \times 0,2590^{0,45} \times 34,77^{0,13}$$

Standarisasi ID $= 3,368465891 \text{ in} \times \frac{16}{16}$

$$= \frac{53,90}{16} = 3\ 1/2$$

= 3 1/2 in sch. 40 (Geankoplis,App. A.5-1 hal 892)

OD = 3,500 in = 0,2917 ft = 0,0889 m

ID = 3,068 in = 0,2557 ft = 0,0779 m

A = 0,0513 ft^2

C. Menentukan kecepatan aliran fluida

$$\text{kecepatan aliran (v)} = \frac{Q}{A} = \frac{0,2590 \text{ ft}^3\text{/s}}{0,0513 \text{ ft}^2}$$

$$= 5,05 \text{ ft/s}$$

Menghitung bilangan Reynold

$$\text{Bilangan Reynold } (N_{re}) = \frac{D\ v\ \rho}{\mu}$$

$$= \frac{0,2557 \times 5,0494 \times 34,7696}{1,2000}$$

$$= 37,40528784 > 2100 \text{ (aliran turbulen)}$$

$\alpha = 1$

Digunakan bahan pipa yang terbuat dari commercial steel, sehingga :

$\varepsilon = 4,6 \times 10^{-5} = 0,000046$ (Geankoplis,Fig. 2.10-3 hal. 88)

$$\frac{\varepsilon}{D} = \frac{0,000046}{0,0779} = 0,000590287$$

f = 0,005

Menentukan panjang pipa (Geankoplis, Table. 2.10-1 hal. 93)

Asumsi :

- Panjang pipa lurus = 100 ft
- elbow 90^o = 3 buah
  - Le/D = 35
  - Le = 35 ID
  - = 35 × 3 × 0,2557
  - = 26,845 ft
- Gate valve = 1 buah
  - Le/D = 9
  - Le = 9 ID
  - = 9 × 1 × 0,2557
  - = 2,3010 ft
- Globe valve = 1 buah
  - Le/D = 300
  - Le = 300 ID
  - = 300 × 1 × 0,2557
  - = 76,7 ft

= 100 + 26,845 + 2,3010 + 76,70

$= \quad 205,8460 \quad ft$

Menentukan friction loss

1. Friksi pada pipa lurus

$$Ff = \frac{4f \times v2 \times \Delta L}{2\ gc\ D}$$

$$= \frac{4 \times \quad 0,005 \quad \times \quad 25,4967 \quad \times \quad 205,8460}{2 \quad \times \quad 32,174 \quad \times \quad 0,2557}$$

$$= \quad 6,3804 \quad lb_f.ft/lb_m$$

2. Contraction loss

$$Kc = 0,55 \times (1-(A_2/A_1))$$

$(A_2/A_1 \quad = \quad 0$ karena nilai $A_1 >>> A_2)$

$$= 0,55$$

$$hc = \frac{Kc \quad v^2}{2\ \alpha \quad gc}$$

$$= \frac{0,55 \quad \times \quad 25,4967}{2 \times \quad 1 \quad \times \quad 32,174}$$

$$= 0,218 \quad lb_f.ft/lb_m$$

3. Expansion loss

$$Kex = (1-(A_1/A_2))^2$$

$$= 1$$

$$hex = \frac{Kex \quad v^2}{2\ \alpha \quad gc}$$

$$= \frac{1 \quad \times \quad 25,4967}{2 \times \quad 1 \quad \times \quad 32,174}$$

$$= 0,3962 \quad lb_f.ft/lb_m$$

4. friksi pada Elbow 90^o 3 buah

$$Kf = 0,75$$ (tabel 2.10-1 Geankoplis hal.93)

$$hf = 3 \ \frac{Kf \quad v^2}{2\ gc}$$

$$= 3 \ \frac{0,75 \quad \times \quad 25,4967}{2 \quad \times \quad 32,174}$$

$$= 0,8915 \quad lb_f.ft/lb_m$$

Sehingga:

Total friksi ($\sum F$) $= Ff + hc + hex + hf$

$= \quad 6,38 \quad + \quad 0,218 \quad + \quad 0,3962 \quad + \quad 0,8915$

$= \quad 7,886 \quad lb_f.ft/lb_m$

Direncanakan:

$\Delta Z = \quad 40 \quad ft$

$\Delta P = 0$ (karena $P_1 = P_{2)}$

$v_1 = 0$ ft/s (karena fluida diam dalam tangki penampung)

$v_2 = 5,049$ ft/s

$\alpha = \quad 1$

Kesetimbangan energi mekanik:

$$\frac{v_2^2 \quad - \quad v_1^2}{2\alpha gc} + \Delta z \ \frac{g}{gc} + \frac{\Delta p}{\rho} + \sum F = -Ws$$

(pers 2.7-28 Geankoplis)

$$\frac{25,497 \quad - \quad 0}{64,348} + \quad 40 \quad \frac{0}{34,770} + \quad 7,886 \quad = \quad -Ws$$

$Ws = \quad -8,3 \quad lb_f.ft/lb_m$

efisiensi pompa (η) $= \quad 68\%$ (Petters, fig. 1437)

$Ws = \quad - \eta \quad Wp$

$-8,3 = \quad 68\% \quad Wp$

$Wp = \quad 12,1798 \quad lb_f.ft/lb_m$

mass flow rate (m) $= Q \quad \times \quad \rho$

$= \quad 932,5275 \quad \times \quad 34,7696$

$= \quad 32423,58721 \quad lbm/jam$

$= \quad 9,0066 \quad lbm/s$

brake horsepower $= \frac{-Ws \quad \times \quad m}{\eta \quad \times \quad 550}$

$= \frac{8,3 \quad \times \quad 9,0066}{}$

$$= 68\% \times \frac{}{550}$$

$$= 0{,}1995 \text{ hp} \approx 1 \text{ hp}$$

efisiensi motor = 80% (Petters, fig. 1438

$$\text{Daya} = \frac{\text{brake horsepower}}{\text{efisiensi motor}}$$

$$= \frac{0{,}1995}{80\%}$$

$$= 0{,}2493 \text{ hp} \approx 1 \text{ hp}$$

3. VAPORIZER ETHANOL (V-113)

Fungsi: Mengubah fase *Ethanol* dari cair menjadi fase uap

Tipe : Shell and Tube

Das Saturated steam = T = 370 ℃

P = 475,8 kpa = 69,009 psia

λ = 452,6 kj/kg = 194,58 btu.lb

Dasar perencanaan

Q massa = 6307996,45 btu/jam

Massa bahan masuk W = 14704,57 kg/jam ####

= 32417,9995 lb/jam

Suhu bahan masuk t_1 = 30 ^oC = 86 F

Suhu bahan keluar t_2 = 100 ^oC = 212 F

Kebutuhan steam (m) = 180363,888 kg/jam = 397630 lb/jam

Panas yang dibawa steam = 19510214,3 kkal/jam = 7,7E+07 btu/jam

Steam masuk pada suhu T_1 = 370 ^oC = 698 F

Steam keluar pada suhu T_2 = 370 ^oC = 698 F

Komponen	Massa (kg/jam)	xi massa	μ (Cp)	μ (lbm/fts)	xi. μ
C_2H_5OH	14631,0518	0,9950	1,2	0,000806364	1,2
H_2O	73,5229	0,0050	0,87	0,000584614	3E-06
Total	14704,5747	1,0000	2,0700	0,001390978	1,2

(Geankoplis Figure A.3-4 Hal 876)

$$\mu \text{ campuran} = \frac{\sum xi.\mu}{\sum xi} = \frac{1{,}200002923}{1} = 1{,}200002923 \text{ kg/m .s}$$

Direncanakan

- Rate Liquid : 14704,57 kg/jam = 32423,5872 lb/jam
- Densitas Liquid : 0,00 lb/ft^3
- Viskositas Liquid : 1,200002923 Cp

Perhitungan

Menghitung Δt

Δt_1 = 698 - 212 ^oF = 486 ^oF

Δt_2 = 698 - 86 ^oF = 612 ^oF

A. Menghitung ΔT_{LMTD}

$$\Delta T_{LMTD} = \frac{\Delta t_1 - \Delta t_2}{\ln\left(\Delta t_1/\Delta t2\right)}$$

$$= \frac{(486 - 612)}{\ln\left(\frac{486}{612}\right)}$$

$$= \frac{-126}{-0{,}231}$$

$$= 546{,}582 \ ^oF$$

B. Menghitung suhu kalorik

Tc = (T_1 + T_2) /2 = 698 F

tc = (t_1 + t_2) /2 = 149 F

C. Trial U_D

Trial U_D jenis Exchanger (D.Q Kern Tab.8 hal 840)

Light organics sehingga dapat di trial nilai U_D berkisar 40-75

Trial harga UD = 75 $Btu/jam.ft^2$

$$A = \frac{Q}{UD \times \Delta t \text{ LMTD}} = \frac{6307996{,}448}{75 \times 546{,}58} = 153{,}8775047 \ ft^2$$

Diambil ukuran pipa 1 in OD, 16 BWG, 1 1/4 in susunan triangular pitch :

a' = 0,594 a'' = 0,2618 (D.Q Kern Tab.10 hal 844)

$$Nt = \frac{A}{a'' \times L} = \frac{153,8775047}{0,2618 \times 12} = 48,98061648$$

Menentukan Nt standart = 52

$$\text{UD koreksi} = \frac{Nt}{Nt\ standard} \times \text{UD trial}$$

$$= \frac{48,98061648}{52} \times 75 = 70,6451199\ /jam.ft^2\,^oF$$

Karena nilai U_D koreksi berada diantara 40-75 maka memenuhi

Dari data diatas dapat disimpulkan hasil perancangan sementara Nt = 52 yaitu :

Bagian sheel				Bagian tube			
ID_S	=	12	in	OD	=	1	in
Passes (n')	=	2	in	ID	=	0,870	in
Pitch	=	1 1/4	in 1,25		=	0,0725	ft
BWG (B)	=	16	in	n	=	2	in
De	=	0,72	in KernFig.2 hal838	a'	=	0,594	in^2
	=	0,06	ft	a''	=	0,2618	ft
L	=	12	ft	c'	=	Pitch - OD	
c'	=	Pt - OD tube			=	1 1/4 - 1	
	=	1/4	0,25		=	1/4	

Evaluasi Perpindahan Panas

Shell (liquid) Preheating

1. Menghitung NRes

$$as = \frac{ID_S \times C' \times BWG}{n' \times Pt \times 144} = \frac{12 \times 0 \times 16}{2 \times 1 \times 144} = 0,13333333\ ft^2$$

Diketahui M dari App A neraca massa :

M = 14704,575 kg/jam = 32417,705 lb/jam

$$Gs = \frac{M}{as} = \frac{32417,71}{0,13333333} = 243132,79$$

μ = 0,500 (Kern Fig.14 hal 823)

$$NRes = \frac{Gs \times de}{\mu \times 2,42} = \frac{243132,79 \times \frac{0,06}{10}}{0,5 \times 2,42} = 1205,6$$

2. Menghitung J_H

J_H = 25 (Kern Fig.28 hal 838)

3. Menghitung ho

$$ho = J_H \left(\frac{k}{de}\right) \times \left(\frac{cp \times \mu}{k}\right)^{1/3}$$

k = 0,0124 (D.Q Kern Tab.5 hal 801)

cp = 0,9 (D.Q Kern Fig.2 hal 804)

$$ho = 25 \left(\frac{0,0124}{0,006}\right) \times \left(\frac{0,9 \times 1}{0,0124}\right)^{1/3}$$

$$= 51,667 \times 6,0241 = 311,24749\ Btu/jam\ ft^2\,^oF$$

Tube (steam)

1. Menghitung NRet

$$at = \frac{Nt \times a'}{n \times 144} = \frac{52 \times 0,59}{2 \times 144} = 0,1073$$

Diketahui M dari App B neraca panas :

M = 1551,7 kg/jam = 3420,8 lb/jam

$$Gt = \frac{M}{at} = \frac{3420,8}{0,1073} = 31896$$

μ = 0 (Kern Fig.15 hal 825)

$$NRet = \frac{Gt \times di}{\mu \times 2} = \frac{31896 \times \frac{0,87}{10}}{0,019 \times 2} = 60350,6$$ (Kern Fig.28 hal 838)

2. Menghitung J_H

J_H = 180

3. Menghitung hi

$$hi = J_H \left(\frac{k}{de}\right) \times \left(\frac{cp \times \mu}{k}\right)^{1/3} \times$$

k = 0,069 (D.Q Kern Tab.5 hal 801)

cp = 0,523 (D.Q Kern Fig.2 hal 804)

$$hi = 180 \left(\frac{0,069}{0,087}\right) \times \left(\frac{1 \times 0,02}{0,069}\right)^{1/3}$$

$$= 142,758621 \times 0,3794924 = 54,1758116\ Btu/jam\ ft^2\,^oF$$

Evaluasi Perpindahan Panas

Shell (liquid) Vaporizing

1. Menghitung NRes

$$as = \frac{ID_S \times C' \times B}{n' \times Pt \times 144} = \frac{12 \times 0 \times 16}{2 \times 1 \times 144} = 0,1\ ft^2$$

Diketahui M dari App A neraca massa :

M = 14705 kg/jam

Tube (steam)

1. Menghitung NRet

$$at = \frac{Nt \times a'}{n \times 144} = \frac{52 \times 0,59}{2 \times 144} = 0,10725$$

Diketahui M dari App B neraca panas :

M = 1551,7 kg/jam

= 32418 lb/jam	= 3420,8 lb/jam
$Gs = \frac{M}{as} = \frac{32417,71}{0,13333333}$	$Gt = \frac{M}{at} = \frac{3420,805}{0,10725}$
= 243132,79	= 31895,62 lb/jam.ft^2
μ = 0,011 (Kern Fig.15 hal 825)	μ = 0,019 (D.Q Kern Fig.15 hal 825)
$NRes = \frac{Gs}{\mu} \times \frac{de}{2,42}$	$NRet = \frac{Gt}{\mu} \times \frac{di}{2,42}$
$NRes = 243132,79 \times \left(\frac{0,06}{10}\right)$	$NRet = 31896 \times \frac{0,87}{10}$
$\frac{0,011}{} \times \frac{2,42}{}$	= 0,019 x 2,42
= 54800,8	= 60350,5547
2. Menghitung J_H	**2. Menghitung J_H**
J_H = 150 (D.Q Kern Fig.28 hal 838)	J_H = 180 (D.Q Kern Fig.28 hal 838)
3. Menghitung ho	**3. Menghitung hi**
$ho = J_H \left(\frac{k}{de}\right) \times \left(\frac{cp \times \mu}{k}\right)^{1/3}$	$hi = J_H \left(\frac{k}{de}\right) \times \left(\frac{cp \times \mu}{k}\right)^{1/3}$
k = 0,0124 (Kern Tab.5 hal 801)	k = 0,069
cp = 0,9 (Kern Fig.2 hal 804)	cp = 0,523
$ho = 150 \frac{0,0124}{0,006} \times \left(\frac{0,9 \times 0,011}{0,0124}\right)^{1/3}$	$hi = 180 \left(\frac{0,069}{0,087}\right) \times \left(\frac{0,523 \times 0,069}{}\right)$
= 310 x 0,89353	= 142,758621
= 276,99278 Btu/jam ft^2 ^{o}F	= 54,1758137

D. Mencari tahanan panas pipa bersih (Uc) Untuk sheel preheating

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

$$= \frac{54,1758116 \times 311,2474899}{54,1758116 + 311,2474899} = 46,1439796 \text{ Btu/jam ft}^2\,^oF$$

$$Ap = \frac{Qp}{U_C + \Delta t\ LMTD}$$

$$= \frac{6307996,448}{46,1439796 + 546,582}$$

$$= 10642,35493$$

E. Mencari tahanan panas pipa bersih (Uc) Untuk sheel vaporizing

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

$$Av = \frac{54,1758116 \times 311,2474899}{54,1758116 + 311,2474899} = 46,1439796 \text{ Btu/jam ft}^2\,^oF$$

$$= \frac{Qv}{U_C + \Delta t\ LMTD}$$

$$Ac = \frac{167845,9742}{46,1439796 + 0,000}$$

$$= 3637,44037$$

$$= Ap + Av$$

$$Uc = 10642,35493 + 3637,44037$$

$$= 14279,7953$$

$$= \frac{\Sigma\ (U \cdot A)}{Ac}$$

$$= \frac{46,1439796 \times 10642,35493 + 46,1439796 \times 3637,44037}{14279,7953}$$

$$= \frac{658926,583}{14279,7953} = 46,1439796$$

F. Mencari dirt factor (faktor kekotoran) pipa terpakai

$$Rd = \frac{Uc + Ud_{koreksi}}{Uc \times Ud_{koreksi}}$$

$$= \frac{46,1439796 + 70,645}{46,1439796 \times 70,645} = 0,03582656 \text{ Btu/jam ft}^2\,^oF$$

Rd hitung (0,0358) > (0,003) Rd ketetapan maka memenuhi

Evaluasi Preasurre Drop (ΔP)	
Shell (gas)	**Tube (steam)**
PREHEATING :	1. Menghitung Nre pipa
1. Menghitung Nre pipa	NRe = 60350,6
NRe = 1205,6	Dari D.Q.Kern fig.29 hal 839 diperoleh :

Dari D.Q.Kern fig.29 hal 839 diperoleh :

f = 0,0038

2. Menghitung harga (N + 1)

N+1 = (10 x L / B)

$= \frac{10 \quad x \quad 12}{16}$

= 7,5

Karena passes, maka N + 1

= 2 x 8

= 15

Harga Sg = 1 (Kern Tab.6 hal 808)

3. Menghitung ΔP

$\Delta Ps = \frac{f \times Gs^2 \times IDs \times (N+1)}{5{,}22 \cdot 10^{10} \times de \times sg \times \phi s}$

$= \frac{0{,}0038 \cdot 243132{,}7904^2 \cdot 12 \cdot 15}{5{,}22 \cdot 10^{10} \cdot 0{,}72 \cdot 0{,}81 \cdot 1}$

= 1,32817454 < 5 psi (memenuhi)

f = 0,0015

2. Menghitung ΔP

Harga Sg = 1,0 Kern fig.29 hal 839

$\Delta Pt = \frac{f \times Gt^2 \times IDs \times (N+1)}{5{,}22 \cdot 10^{10} \times di \times sg \times \phi s}$

$= \frac{0{,}0015 \cdot 31895{,}61503^2 \cdot 12 \cdot 15}{5{,}22 \cdot 10^{10} \cdot 0{,}87 \cdot 1{,}0 \cdot 1}$

= 0,00604834 psi

3. Menghitung ΔP karena tube passes

(D.Q Kern Fig.27 hal 837)

$\frac{V^2}{2gc} \times \frac{\rho}{144} =$ 0,007

Jadi

$\Delta Pn = \left(\frac{4 \cdot n}{sg} \right) \times$ 0,007

$= \left(\frac{4 \cdot 2}{1{,}0} \right)$

= 0,056 psi

4. Menghitung ΔP total pada bagian tube

ΔP total = ΔPt + ΔPn

= 0,006 + 0,056

= 0,06204834 psi

0,06204834 < 10

Spesifikasi Alat Vaporize : Vaporizer

Nama alat	:	Mengubah fase ethanol cair menjadi gas					
Fungsi	:	Shell and Tube					
Type	:	High alloy steel SA - 240 grade M tipe 316					
Bahan kontruksi							
Bagian sheel					Bagian tube		
ID_S	= 12	in		OD	= 1	in	
Passes (n')	= 2	in		ID	= 0,870	in	
Pitch	= 1 1/4	in	1,25		= 0,0725	ft	
BWG (B)	= 16	in		n	= 2	in	
De	= 0,72	in	(D.Q Kern Fig.28 hal 83	a'	= 0,0594	in^2	
	= 0,06	ft		a"	= 0,2618	ft	
L	= 12	ft		c'	= Pitch -	OD tube	
c'	= Pt -	OD tube			= 1 1/4 -	1	
	= 1/4	0,25			= 1/4		

4. COMPRESSOR (G-114)

Fungsi : Mengkompresi gas dari keluaran Vaporizer menuju Reakt

Tipe : *Recyprocating compressor*

Kondisi operasi:

- T_1 = 100 °C = 373,15 K
- p_1 = 1 atm
- p_2 = 2,9 atm
- η = 90%
- Kompresi Isotherr

Komponen	Massa kg/jam	Densitas (ρ) kg/m^3	xi	xi.ρi
C_2H_5OH	14631,0518	555,00	0,995	552,225
H_2O	73,5229	995,95	0,005	4,980
Total	14704,5747	1550,95	1,000	557,205

(Perry's 8th, tabel 2-112 dan 2-30)

ρ campuran $= \frac{\Sigma xi.\rho i}{\Sigma xi}$

$= \frac{557{,}2047}{} =$ 557,2 kg/m^3 = 34,77 lb/ft^3

1,000

Direncanakan: = 14.704,57 kg/jam = 32.423,59 lb/jam
Massa gas = 557,2 kg/m^3
Densitas gas (dianggap sama dengan densitas campu = 34,8 lb/ft^3
Rate gas = 32423,5872 / 34,7696
= 932,5275 ft^3/jam

Menghitung Mr rata-rata

Komponen	Massa	kgmol/jam
C_2H_5OH	14631,0518	318,0663
H_2O	73,5229	4,0846
Total	14704,5747	322,1509

Mr average = total massa / total mol
= 14704,5747 / 322,151
= 45,6450 kg/kgmol

m = 322,1509 kgmol/jam
= 0,0895 kgmol/s
= 0,0895 / 45,645
= 0,0020 kg/s

Daya teoritis untuk menggerakkan kompressor

$$-Ws = \frac{y}{y-1}\frac{RT_1}{M}\left[\left(\frac{P_2}{P_1}\right)^{(y-1)/y} - 1\right]$$

$$= \frac{1,4}{1,4 - 1} \times \frac{8314,3 \times 373,15}{45,6450} \times \left(4^{\frac{1.4-1}{1.4}} - 1\right)$$

= 115615,30 J/kg

brake = -Ws m / η.1000
kW = 115615,30 x 0,0020 / 90% x 1000
= 0,25185 kW
= 0,33760 hp ≈ 1 hp

5. HEATER ETHANOL (E-115)

Fungsi : untuk menaikkan suhu ethanol dari 100 °C hingga 350 °C
tipe : Shell and tube
Bahan kontruksi : Carbon steel SA 53 Grade B

Direncanakan

- faktor pengotor gabungan minimum (R) = 0,003 jam ft2 F/Btu
- penurunan tekanan aliran maksimum (Δp) = 10 psi

Kondisi operasi

- massa bahan masuk (W) = 14631,052 kg/jam
  = 32255,617 lb/jam
- suhu bahan masuk (t_1) = 100 ºC = 212 ºF
- suhu bahan keluar (t_2) = 350 ºC = 662 ºF
- kebutuhan pemanas (m) = 1126,9895 kg/jam
  = 2484,5610 lb/jam
- panas yang dibawa steam (Q) = 121908,03 kkal/jam
  = 483447,014 btu/jam
- suhu pemanas masuk (T_1) = 370 ºC = 698 ºF
- suhu pemanas keluar (T_2) = 370 ºC = 698 ºF
- arah aliran = *Counter Current*

Komponen	Massa (kg/jam)	xi massa	μ (Cp)	μ (lbm/fts)	xi. μ
C_2H_5OH	14631,0518	0,9950	1,2	0,000806364	0,0008023
H_2O	73,5229	0,0050	0,87	0,000584614	2,923E-06
Total	14704,5747	1,0000	2,0700	0,001390978	0,0008053

(Geankoplis Figure A.3-4 Hal 876)

μ campuran $= \frac{\sum xi.\mu}{\sum xi} = \frac{0{,}000805255}{1} =$ 0,000805255 kg/m .s

Perhitungan :

A. Menghitung Δt

$\Delta t_1 = T_1 - t_2 =$ 698 - 212 = 486 ^{0}F

$\Delta t_2 = T_2 - t_1 =$ 698 - 662 = 36 ^{0}F

maka, $\Delta T_{LMTD} = \frac{\Delta t_1 - \Delta t_2}{\ln \frac{\Delta t_1}{\Delta t_2}} = \frac{486{,}00 - 36}{\ln \frac{486{,}00}{36}} = \frac{450{,}00}{2{,}6027} =$ 172,9 ^{0}F

$\Delta t = Ft \times \Delta T_{LMTD} =$ 0,9 × 172,898 = 155,61 ^{0}F

B. Menghitung Suhu Kalorik (Tc dan tc)

Tc = ($T_1 + T_2$) / 2 = 698,0 ^{o}F

tc = ($t_1 + t_2$) / 2 = 437,0 ^{o}F

C. Trial ukuran Shell and tube

Trial UD

Dari *D.Q. Kern* tabel 8 hal 840 untuk light organic dan steam memiliki :

UD = 100-200 Btu/j ft$^{2\,o}$F

Dicoba UD = 100 Btu/j ft$^{2\,o}$F

$A = \frac{Q}{Ud.\Delta t} = \frac{2484{,}5610}{1556{,}082549} =$ 1,5967 ft2 0,486643358

Dari *D.Q Kern* tabel 10 hal. 843 diperoleh :

a" = 0,1963 ft^2/ft

l = 16

$Nt = \frac{A}{a".l} = \frac{1{,}5967}{3{,}1408} =$ 0,5084

Nt standarisasi

Nts = 60

Dari *D.Q Kern* tabel 9 hal. 842 diperoleh :

Shell: ID : 10 in **Tube :** OD 3/4 in

Baffle : 5 Passes: 4 16 BW Triangular

passes: 2 di = 0,62 in

de = 0,55 in = 0,0517 ft

= 0,0458 ft

Evaluasi Perpindahan Panas	
Bagian *Shell* (Bahan)	**Bagian Tube (steam)**
1. Menghitung NRe	**1. Menghitung Nre Tube**
$G_s = \frac{W}{a_s}$ $P_T =$ 1	$G_T = \frac{m}{a_T}$ a'
= 32255,617 lb/jam / 0,6944 ft^2	= 2484,5610 lb/jam / 0,0190 ft^2
= 46448,09 lb/jam.ft^2	= 131053,77 lb/jam.ft^2
	(D.Q Kern Fig. 14 hal. 823)
μ = 0,00080526 lb.ft/jam	μ = 2,1045 lb.ft/jam
$Nre_s = \frac{G_s \times de}{\mu}$	$Nre_1 = \frac{G_T \times di}{\mu}$
= 46448 × 0,0458 / 0,0008	= 131053,77 × 0,052 / 2,1045
= 3E+06	= 3238,1557
= ### (Interpolasi Kern Fig. 28 9 hal. 838)	2. JH = 22
2. JH = 20 Btu/j.ft2.^{o}F	(D.Q Kern Fig. 28 9 hal. 838)
(D.Q Kern Fig. 28 9 hal. 838)	
3. Menghitung harga koefisien film	3. Menghitung harga koefisien film
$ho = J_H \left(\frac{k}{de}\right) x \left(\frac{cp \times \mu}{k}\right)^{1/3}$	$hi = J_H \left(\frac{k}{de}\right) x \left(\frac{cp \times \mu}{k}\right)^{1/3}$
k = 0,1536 (Perry's 8th, tabel 2-194)	k = 0,0248 (D.Q Kern Table. 5 hal. 804)
cp = 1 (D.Q Kern Fig. 2 hal. 804)	cp = 1,2 (D.Q Kern Fig. 2 hal. 804)

ho = 20 $\frac{0,1536}{0,0458}$ x $\left(\frac{1 \times 0,0008}{0,1536}\right)^{1/3}$	hi = 22 $\left(\frac{0,0248}{0,0517}\right)$ x $\left(\frac{1,2 \times 0,87}{0,0248}\right)$
= 67,025 x 0,07240544	= 10,56 × #REF!
= 4,85300728 Btu/jam ft^2 ^{o}F	= #REF! Btu/j.ft2.^{o}F

D. Mencari tahanan panas Tube bersih

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

$= \frac{4,85300728 \times \#REF!}{4,85300728 + \#REF!}$

= #REF! Btu/jam.ft^2.^{o}F

E. Mencari dirt factor (faktor kekotoran) Tube terpakai

Menghit Rd $= \frac{U_C + U_D}{U_C \times U_D}$

$= \frac{\#REF! + 100}{\#REF! \times 100}$

= 0,237

Rd Rd hitung (0,237) > (0,003) Rd ketetapan maka memenuhi

Shell	Tube
Re = 1686,23	Re = 3238,16
= 0,0036 (D.Q Kern Fig. 28 hal. 8	f = 0,0032 (D.Q Kern Fig. 28 hal. 838)
f = 0,81 (D.Q Kern Tab.26 hal. 8	s = 0,81 (D.Q Kern Tab.26 hal. 808)
s = ID shell = 10	
Ds = $\frac{10}{12}$ = 0,83 ft	ΔPt = $\frac{f \times Gt^2 \times L \times n}{5,22 \times 10^{10} \times D \times s \times \phi t} \times \frac{1}{2}$
= 12L/B = 38,4	= 0,06708907 psi
N+1 = ΔPs = $\frac{f \times Gs^2 \times Ds \times (N+1)}{5,22 \times 10^{10} \times De \times s \times \phi s}$	ΔPt < ΔP tetapan
= 0,1282 psi	0,0671 < 10
	maka memenuhi syarat
ΔPs < ΔP tetapan	
0,1282 < 10	
maka memenuhi syarat	

6. REAKTOR (R-110)

Perancangan alat utama BAB VI (Dwi Indah Nur Kofifa NIM. 1814019)

7. COOLER (E-116)

Fungsi : Menurunkan suhu dari 350 ^{o}C menjadi 50 ^{o}C menggunakan refrigerant

Type : Sheel and Tube

Dasar perencanaan :

- P operasi	=	1	atm			
- T bahan masuk (t_1	=	350	^{o}C	=	662	^{o}F
- T bahan keluar (t_2	=	50	^{o}C	=	122	^{o}F
- T steam masuk (T	=	-161	^{o}C	=	-257,8	^{o}F
- T steam keluar (T	=	138	^{o}C	=	280,4	^{o}F
- Rate (m)	=	14704,575	kg/jam	=	32417,7054	lb/jam

A. Material dan Heat Balance

Q = m x λ

Dari appendik B neraca panas didapatkan data sebagai berikut:

Hv = 2342,8	ΔH_1	=	11564181,1			
Hl = 1890,2	ΔH_2	=	246243,2592			
λ = Hv - Hl	Q_{loss}	=	765,4172			
= -172,4	ΔH_1	=	$Q_{refrigerant}$	+ ΔH_2	+	Q_{loss}
	11564181,1	=	$Q_{refrigerant}$	+ 246243,2592	+	231283,6226
Q = m x l	$Q_{refrigerant}$	=	11564181,1	- 246243,2592	+	231283,6226
Q = 32418 x -172,422	$Q_{refrigerant}$	=	11086654,2			
Q= -5589525,59717						

B. mencari panas Δt LMTD

Δt LMTD = $\frac{\Delta t1 - \Delta t2}{\ln \Delta t1/\Delta t2}$

Δt1 = T1 - t2 = -257,8 - 122 = -379,8 F

$\Delta t2 = T2 - t1 = 280,4 - 662 = -381,6$ F

$\Delta t\ LMTl = \frac{-379,8 - -381,6}{\ln \Delta t1/\Delta t2} = \frac{1,8}{-0} = -380,7$ F

C. Menghitung suhu caloric (Tc dan tc)

$Tc = \frac{1}{2} T1+T2 = \frac{1}{2} -258 \quad 280,4 = 11,2$ F

$Tc = \frac{1}{2} t1+t2 = \frac{1}{2} 662 + 122 = 392$ F

D. Trial Ud

Trial ud jenis exchanger

Light organik sehingga dapat ditrial nilai Ud berkisar 40-75

Trial harga UD = 75 Btu/jam.ft2

$A = \frac{Q}{UD \times \Delta t\ LMTD} = \frac{-5589525,59717}{75 \times -380,7} = 195,7634536$

Diambil ukuran 3/4 in OD, 16 BWG, 1 5/16 in susunan triangular pitch:

a' = 0,302 a" = 0,1963 Kern, tabel 10 hal: 843

$Nt = \frac{A}{a" \times L} = \frac{195,7634536}{0,1963 \times 10} = 99,7266702$

Menentukan Nt standart= 138

UD koreksi $= \frac{Nt}{Nt\ standard} \times$ UD trial

$= \frac{99,72667022}{138} \times 75 = 54,1992773$ Btu/jam.ft^2 ^{o}F

Dari data diatas dapat disimpulkan hasil perancangan sementara Nt = 56 yaitu:

Bagian sheel			Bagian tube			
IDs	=	17,25	OD =	0,8	in	
Passes (n')	=	2	ID =	0,620	in	
Pitch	=	1,312	=	0,051	ft	
BWG (B)	=	16	n =	1	in	
de	=	0,55 in	a' =	0,302	in	Kern, figur 28 hal:838 (de)
	=	0,0457 ft	a" =	0,1963	ft	
L	=	10 ft	c' =	Pt-OD tube		
c'	=	Pt - OD tube	=	1,3 - 0,75		
	=	1 - 0,8	=	0,6	in	
	=	0,562 in				

Evaluasi Perpindahan Panas	
Shell (Gas)	**Tube (refrigerant metana)**
1. Menghitung Nres	1. Menghitung Nret
$as = \frac{x\ c'\ x\ B}{n'\ x\ Pt\ x\ 144}$	$at = \frac{Nt\ x\ a'}{n\ x\ 144}$
$= \frac{17 \times 0,6 \times 16}{2 \times 1,3 \times 144}$	$= \frac{138 \times 0,302}{1 \times 144}$
= 0 ft2	= 0,2894
Diketahui M dari App A neraca massa:	Diketahui M dari App B neraca panas:
M = 146,31 kg/jam	M = 146,310518 kg/jam
= 322,56 lb/jam	= 322,556169 lb/jam
$Gs = \frac{M}{as} = \frac{323}{0,4}$	$Gt = \frac{M}{at} = \frac{323}{0,3}$
= 785,75	= 1114,5
m = 0,018 (D.Q Kern Fig. 15 hal. 804)	μ = 1,2
$NRes = \frac{Gs \times de}{m \times 2,42}$	$NRet = \frac{Gt \times di}{m \times 2,42}$
$NRes = \frac{785,75 \times 0,55}{0,018 \times 2,42} = 9921,12897$	$NRet = \frac{1114,504469 \times 0,620}{1,2 \times 2,42} = 237,945$
2. Menghitung jH	2. Menghitung jH
jH = 50 (D.Q Kern Fig. 28 hal. 838)	jH = 9 (D.Q Kern Fig. 28 hal. 838)
3. Menghitung ho	3. Menghitung hi
$ho = jH \left[\frac{k}{de}\right] \times \left[\frac{cp \times m}{k}\right]^{1/3}$	$hi = jH \left[\frac{k}{di}\right] \times \left[\frac{cp \times m}{k}\right]^{1/3}$
k = 0 (D.Q Kern Table. 5 hal. 801)	k = 0,124 (D.Q Kern Table. 4 hal. 800)
cp = 0,7 (D.Q Kern Fig. 2 hal. 804)	cp = 0,69 (D.Q Kern F
	$hi = 9 \left[\frac{0,124}{} \right] \times \left[0,69 \times 1,200\right]$

ho	=	50 [0 / ###]	x	0,68 x 0,018 / 0,01				
	=	1	x	1,0696		=	1,8 x 1,881891935	
	=	0,97238562		Btu/jam.ft^{2} ^{o}F		=	3,387405482	Btu/jam.ft^{2} ^{o}F

4. Mencari tahanan panas pipa bersih (Uc) untuk sheel preheating

$$Uc = \frac{hi \times ho}{hi + ho} = \frac{3,3874 \times 1}{3,3874 + 1} = 0,755509679 \text{ Btu/jam.ft}^{2}\,^{o}\text{F}$$

5. Mencari dirt factor (faktor kekotoran) pipa terpakai

$$Rd = \frac{Uc + koreksi}{Uc \times koreksi} = \frac{0,8 + 54}{0,8 \times 54} = 1,3$$

Rd hitung (0,416501479) > (0,003) Rd ketetapan maka memenuhi

Evaluasi Preassure drop	
Shell (gas)	**Tube (refrigerant metana)**
Preheating	
1. Menghitung Nre pipa	1. Menghitung Nre pipa
Nre = 9921,1	Nre = 237,945
(D.Q Kern Fig. 28 hal. 839)	(D.Q Kern Fig. 28 hal. 839)
f = 0,0021	f = 0,0049
2. Menghitung harga N+1	2. Menghitung DP
N+1 = (10 x L/B)	Harga Sg = 0,82
= 10 x 10 / 16	DPt = f x Gt^2 x IDs x (N+1) / 5,22.10^10 x di x Sg x
= 6,3	= 0,0049x1114,504469^2x17,25x12,5 / 5,22.10^10x0,620x0,82x1
Karena passes, maka N+1	= 0,00059581 psi
= 2 x 6	3. Menghitun DP karena tube passes
= 13	Dari Kern fig 27 hal 837 didapatkan:
Harga Sg = 0,8 (D.Q Kern Tab.6 hal 808)	
3. Menghitung ΔP	V^2/2gc x r/144 = 0,0001
D Ps = f x Gs^2 x IDs x (N+1) / 5,22.10^10 x de x Sg x fs	Jadi;
= 0,0021 ## x 17 x 12,5 / 5,22.10^10 x ### x 0,81 x ###	DPn = [4 . n / sg] x V^2/2sg x r/144
= 1,2022E-05	= [4 x 1 / 0,82] x 0,0001
DPs = 1,2022E-05 < 5 psi (memenuhi)	=
	4. Menghitun DP total pada bagian tube
	DP total = 0 DPt + DPn
	= ###### + 0,000488
	= ###### psi
	0,00108 < 10 psi (memenuhi)

Spesifikasi Alat Cooler:

Nama alat : Cooler
Fungsi : Menurunkan suhu dari 350C menjadi 50C sebelum masuk flashdrum
Tipe : Shell and Tube
Bahan kontruksi : Carbon steel SA 53 Grade B

IDs	=	17,25		OD	=	0,8	in
Passes (n')	=	2		ID	=	0,620	in
Pitch	=	1,312			=	0,051	ft
BWG (B)	=	16		n	=	1	in
de	=	0,55	in				
	=	0,0457	ft				
L	=	10	ft	c'	=	Pt-OD tube	
c'	=	Pt - OD tube			=	1,3 - 0,75	
	=	1 - 0,8			=	0,6	in
	=	0,562	in				

8. FLASH DRUM (D-117)

Fungsi : Memisahkan fase gas dan liquid yang keluar dari cooler

Tipe : Silinder vertikal dengan tutup atas dan tutup bawah berbe standar dish

Direncanakan :

Bahan kontruksi = Carbon steels SA-240 Grade M Type 316

Tipe pengelasan = Double-welded butt joint

Faktor pengelasan (E) = 0,8 (Brownel, hal 254)

Faktor korosi (C) = 1/16 in

Allowable stresss (*f*) = 18750 psi (Brownel, hal 342)

Waktu tinggal = 15 menit

Volume ruang kosong = 20% Volume total

Kondisi operasi : = 30 ^{o}C = 303,15 K

Suhu operasi = 1 atm = 14,696 psia

Tekanan operasi

Perhitungan *density*

Komponen	A	B	n	Tc
C_2H_5OH	0,2657	0,26395	0,2367	516,25
H_2O	0,3471	0,274	0,28571	647,17
C_2H_4	0,21428	0,28061	0,28571	282,36

Komponen	Massa (Kg/jam)	xi (massa)	ρ (g/cm^3)	xi.ρi
C_2H_5OH	53,49909359	0,00605	1,0066	0,0061
H_2O	14,15	0,00160	1,2668	0,0020
C_2H_4	8770,877626	0,99235	0,7636	0,7578
Total	8838,525324	1,00000	3,0370	0,7659

ρ campuran $= \frac{\sum xi.\rho i}{\sum xi}$

$= \frac{0,77}{1,00} = 0,76589848$ g/cm^3 47,8142765 lb/ft^3

= 8838,525324 kg/jam

Rate bahan masuk = 19485,41293 lb/jam

= 15 menit

Waktu tinggal = 0,25 jam

PERHITUNGAN

A. Menghitung Volume Tangki

Untuk menentukan volume tangki, maka diasumsikan

- Waktu tinggal = 15 menit = 0,25 jam
- Volume ruang kosong = 20% Volume total

Sehingga,

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

$= \frac{19485,4129}{47,8142765}$ x 0,25 jam

= 101,880727 ft^3

Volume total = volume liquid + volume ruang kosong

= 101,8807 + 20% volume total

80% volume total = 101,8807

Volume total = 127,35 ft^3

B. Menentukan Dimensi Tangki

Asumsi Ls = 3 di

Volume total = 2 x V tutup + V silinder

127,35 = 0,1694 di^3 + $\frac{\pi}{4}$ di^{2}Ls

127,35 = 0,1694 di^3 + $\frac{\pi}{4}$ di^2 × 3 di

127,35 = 2,5244 di^3

di^3 = 50,44799092

di = 3,6950 ft

= 44,34 in 66332,64

C. Menghitung Tinggi Liquida Dalam Tangki

V liquida = V liquida dalam silinder + V tutup bawah

101,8807266 = $\frac{\pi}{4}$ di^2Lls + 0,0847 di^3

101,8807266 = $\frac{\pi}{4}$ x 13,6530 x Lls + 4,2729

101,8807266 = 10,71763362 Lls + 4,2729

Lls = 9,107213887 ft

= 109,287677 in

D. Menentukan Tekanan Design

Tekanan hidrostaik (Ph) = $\frac{\rho\ (H-1)}{144}$ (Brownell & Young pers 3,17 hal 46)

= $\frac{47,8\ lb/ft^3 \times 9,1\ ft - 1}{144}$

= 2,69194838 psia

Tekanan design (Pi) = $P_{operasi} + P_{hidrostatik}$

= 14,696 + 2,69194838

= 17,38794838 psia

= 2,692 psig

E. Menghitung Tebal Silinder

Tebal silinder = $\frac{Pi\ di}{2(fE - 0,6Pi)} + C$

= $\frac{2,692 \times 44,3405}{2 \times 18750 \times 0,8 - 0,6 \times 2,692} + \frac{1}{16}$

= 0,06647917 x $\frac{16}{16}$

= $\frac{1,063666724\ in}{16} \approx \frac{3}{16}$ in

Standarisasi do

do = di + 2 ts

= 44,340 + 2 x $\frac{3}{16}$

= 44,7154691 in ≈ 48 in = 4,0 ft

F. Menghitung Tinggi Silinder

Tinggi Silinder (Ls) = 3 × di

= 3 × 3,6950 ft

= 11,0850047 ft

= 133,020056 in

G. Menghitung Dimensi Tutup Atas Dan Tutup Bawah

Bentuk tutup atas dan bawah adalah standar dish, sehingga :

r = di_{baru}

Tebal tutup (th) = $\frac{0,885 \times Pi \times r}{2(fE - 0,1Pi)} + C$

= $\frac{0,885 \times 2,692 \times 44,3405}{2 \times [(18750 \times 0,8 - 0,1 \times 2,692)} + \frac{1}{16}$

= 0,0660 x $\frac{16}{16}$

= $\frac{1,05633999}{16} \approx \frac{3}{16}$ in

Tinggi tutup (h) = 0,169 x di

= 0,169 x 44,34

= 7,493539281 in

= 0,624461607 ft

H. Menghitung Tinggi Tangki (H)

Tinggi tangki (H) = Tinggi silinder + Tinggi tutup atas dan bawah

= 133,0200558 + 2 x 7,493539281

= 148,007 in

= 12,334 ft

Spesifikasi FLASH DRUM (D-117)

Nama : Flash Drum

Kode Alat : D-120

Fungsi	:	Memisahkan fase gas dan liquid yang keluar dari kondensor	
Bahan Kontruksi	:	Carbon steels SA-240 Grade M Type 316	
Kapasitas	:	127,35	ft^3
Suhu Operasi	:	50	^oC
Tekanan Operasi	:	1	atm
Dimensi			
Diameter dalam (di)	:	3,70	ft
Diameter luar (do)	:	4,000	ft
Tinggi Silinder (Ls)	:	11	ft
Tinggi Flash Drum (H)	:	12	ft
Tinggi Tutup Atas (ha)	:	1	ft
Tinggi Tutup Bawah (hb)	:	1	ft
Tebal Silinder (ts)	:		in
Tebal Tutup Atas (tha)	:		in
Tebal Tutup Bawah (thb)	:		in

9. ADSORBER (D-112)

Perancangan alat utama BAB VI (Abdurrahman NIM. 1814033)

10. KONDENSOR (E-121)

Fungsi: menurunkan suhu dari 50C menjadi -130C sehingga merubah fase uap menjadi cair

Tipe : Shell and Tube

Dasar perencanaan:

- P operasi = 1 atm
- T pendingin masuk (t1) = -161 ^oC = -257,8 F
- T pendingin keluar (t2) = 20 ^oC = 68 F
- T bahan masuk (T1) = 50 ^oC = 122 F
- T bahan keluar (T2) = -130 ^oC = -202 F
- Rate (m) = 8839 kg/jam
  = 19485,41293 lb/jam

Q = m x l

Q = 19485,4 x 452,6

Q= 8819097,892

Hv = 2342,8

HL = 1890,2

l = Hv - HL

= 2342,8 - 1890,2

= 452,6

A. mencari panas Δt LMTD

$$\Delta t\ LMTD = \frac{\Delta t1 - \Delta t2}{\ln \Delta t1/\Delta t2}$$

$\Delta t1$ = T1 - t2 = 122 - 68 = 54 F

$\Delta t2$ = T2 -t1 = -202 - -257,8 = 55,8 F

$$\Delta t\ LMTD = \frac{54 - 56}{\ln \Delta t1/\Delta t2} = \frac{-1,8}{-0,0327898} = 55\ F$$

B. Menghitung suhu caloric (Tc dan tc)

$$Tc = \frac{1}{2} T1+T2 = \frac{1}{2} 122 + -202 = -40\ F$$

$$tc = \frac{1}{2} t1+t2 = \frac{1}{2} -258 + 68 = -94,9\ F$$

C. Trial Ud

Trial ud jenis exchanger

Light organik sehingga dapat ditrial nilai Ud be (D.Q Kern Tab.8 hal 840)

Trial harga UD = 75 Btu/jam.ft2

$$A = \frac{Q}{UD \times \Delta t\ LMTD} = \frac{8819097,89184}{150 \times 54,895} = 1071,0247\ ft^2$$

Diambil ukuran 1 1/2 in OD, 16 BWG, 1 7/8 in susunan triangular pitch:

a' = 1,47 a" = 0,3925 (D.Q Kern Tab.10 hal 843)

$$Nt = \frac{A}{a'' \times L} = \frac{1071,024657}{0,3925 \times 40} = 68,218131$$

Menentukan Nt standart= 48

$$\text{UD koreksi} = \frac{Nt}{Nt\ standard} \times \text{UD trial}$$

$$= \frac{68,21813101}{48} \times 75 = 106,59083\ Btu/jam.ft^2\ ^oF$$

Dari data diatas dapat disimpulkan hasil perancangan sementara Nt = 48 yaitu:

Bagian sheel					Bagian tube				
IDs	=	171/4	in	17,3	OD	=	1,5 2	in	(D.Q Kern Tab .10 hal 843)
Passes (n')	=	1	in		ID	=	1,4	in	
Pitch	=	1 7/8	in	1,88		=	0,1	ft	
BWG (B)	=	16	in		n	=	2	in	
de	=	1,08	in		a'	=	1,5	in	(D.Q Kern Fig.28 hal 838 de)
	=	0,0896	ft		a''	=	0,3925	ft	
L	=	12	ft		c'	=	Pt-OD tube		
c'	=	Pt - OD tube				=	1,9 - 1,5		
	=	2 - 1,5				=	0,4	in	
	=	0,375	in						

Evaluasi Perpindahan Panas

Shell (Gas)	**Tube (Refrigerant metane)**
1. Menghitung Nres	1. Menghitung Nret
$as = \frac{IDs \times c' \times B}{n' \times Pt \times 144}$	$at = \frac{Nt \times a'}{n \times 144}$
$= \frac{17 \times 0 \times 16}{1 \times 2 \times 144}$	$= \frac{48 \times 0,393}{1,5 \times 144}$
$= 0,4$ ft2	$= 0,1$
Diketahui M dari App A neraca massa:	Diketahui M dari App B neraca panas:
M = 8838,53 kg/jam	M = 3553,54009 kg/jam
= 19485,4129 lb/jam	= 7834,13448 lb/jam
$Gs = \frac{M}{as} = \frac{8838,53}{0,38333333}$	$Gt = \frac{M}{at} = \frac{7834,1}{0}$
= 23057,02258	= 88022
μ = 0 (D.Q Kern Fig.14 hal 823)	μ = 60 (D.Q Kern Fig.14 hal 823)
$NRes = \frac{Gs \times de}{\mu \times 2,4}$	$NRet = \frac{Gt \times di}{\mu \times 2,42}$
$NRes = \frac{23057,0226 \times 1,1}{0,012 \times 2,4} = 857492,5755$	$NRet = \frac{88022 \times 1,370}{60 \times 2,42}$
2. Menghitung jH	= 830,508
jH = 582 (D.Q Kern Fig. 28 hal. 838)	2. Menghitung jH
3. Menghitung ho	jH = 200 (D.Q Kern Fig. 28 hal. 838)
$ho = J_H \left(\frac{k}{de}\right) \times \left(\frac{cp \times \mu}{k}\right)^{1/3}$	k = 0,007 (D.Q Kern Table. 5 hal. 801)
k = 0 (D.Q Kern Table. 5 hal. 801)	cp = 0,2 (D.Q Kern Fig. 2 hal. 804)
cp = 0,8 (D.Q Kern Fig. 2 hal. 804)	$hi = jH \left(\frac{k}{di}\right) \times \left[\frac{cp \times m}{k}\right]$
$ho = 582 \left(\frac{0,01}{0,0896}\right) \times \left(\frac{0,8 \times 0,01}{0,01}\right)^{1/3}$	$hi = 200 \times \frac{0,007}{1,370} \times \frac{0,2 \times 60.000}{0,007}$
= 64,9263722 x 1,00399203	= 1,02189781 x 11,9384
= 65,1855603 Btu/jam ft^2 °F	= 12,19982482 Btu/jam ft^2 °F

D. Mencari tahanan panas pipa bersih (Uc) Untuk sheel preheating

$$Uc = \frac{hio \times ho}{hio + ho} = \frac{12,1998 \times 65,1856}{12,1998 + 65,1856} = 10,2765 \text{ Btu/jam } ft^2 \text{°F}$$

E. Mencari dirt factor (faktor kekotoran) pipa terpakai

$$Rd = \frac{Uc - Ud_{koreksi}}{Uc \times Ud_{koreksi}} = \frac{10,2765 + 106,591}{10,2765 \times 106,591} = 0,1067 \text{ Btu/jam } ft^2 \text{°F}$$

Rd hitung (0,1067) > (0,003) Rd ketetapan maka memenuhi

Evaluasi Preasurre Drop (ΔP)

Shell (Gas)	**Tube (Refrigerant metane)**
PREHEATING :	
1. Menghitung Nre pipa	1. Menghitung Nre pipa
NRe = 857493	NRe = 830,5
Dari Kern fig 29 hal 839 diperoleh :	Dari Kern fig 29 hal 836 diperoleh :
f = 0,0012	f = 0,0006
2. Menghitung harga (N + 1)	2. Menghitung ΔP
N+1 = (12 x L / B)	Harga $S_ξ$ = 0,8

= 12 x 12
16
= 9
Karena passes, maka N + 1
= 2 x 9
= 18
Harga Sg = 0,8 (D.Q Kern Tab.6 hal 808)

3. Menghitung ΔP

$$\Delta Ps = \frac{f \times Gs^2 \times IDs \times (N+1)}{5{,}22 \cdot 10^{10} \times de \times sg \times \phi s}$$

$$= \frac{0{,}0012 \cdot 23057{,}02258 \cdot 17{,}25 \cdot 18}{5{,}22 \cdot 10^{10} \cdot 1{,}08 \cdot 0{,}81 \cdot 1}$$

= 0,05205366

ΔPs = 0,05205366 < 5 psi
(memenuhi)

$$\Delta Pt = \frac{f \times Gt^2 \times IDs \times (N+1)}{5{,}22 \cdot 10^{10} \times di \times sg \times \phi s}$$

$$= \frac{{,}0006 \cdot 101278{,}2587 \cdot 1{,}37 \cdot 1}{5{,}22 \cdot 10^{10} \cdot 1{,}37 \cdot 0{,}8 \cdot 1}$$

= 0,02461432

3. Menghitung ΔP karena tube passes
Dari "Kern" fig 27, hal 837 diperoleh :

$$\frac{V^2}{2gc} \times \frac{\rho}{144} = 0{,}0001$$

Jadi

$$\Delta Pn = \frac{4n}{sg} \times \frac{V^2}{2gc} \times \frac{\rho}{144}$$

$$= \frac{4 - 2}{0{,}8} \times 0{,}0001$$

= 0,00097561 psi

4. Menghitung ΔP total pada bagian tube
ΔP total = ΔPt + ΔPn
= 0,0246 + 0,0009756
= 0,0256 psi
0,02558993 < 10
(Memenuhi)

Spesifikasi Alat Kondensor :

Nama alat	:	Kondensor
Fungsi	:	Merubah fase gas menjadi liquid pada suhu -130 ^{o}C dalam flash drum
Type	:	Sheel and tube
Bahan kontruksi	:	Carbon steel SA 53 Grade B

Bagian sheel				Bagian tube				
IDs	=	171/4	in	OD	=	1 1/2	2 in	(D.Q Kern Tab .10 hal 843)
Passes (n')	=	1	in	ID	=	1,370	in	
Pitch	=	1 7/8	in	1,88	=	0,114	ft	
BWG (B)	=	16	in	n	=	2	in	
de	=	1,08	in	a'	=	1,470	in	(D.Q Kern Fig.28 hal 838 de)
	=	0,0896	ft	a''	=	0,3925	ft	
L	=	12	ft	c'	=	Pt-OD tube		
c'	=	Pt - OD tube			=	1,9 - 1,5		
	=	2 - 1,5			=	0,4	in	
	=	0,375	in					

11. STORAGE ETILEN (F-122)

Fungsi : Tempat penyimpanan etilen selama 3 hari
Type : Tangki berbentuk bola spherical
Dasar perancanaan
Direncanakan
Bahan konstruksi : High Alloy Steel SA 240 Grade M Type 316
F *allowable* : 18750
Tipe pengelasan : Double welded butt joint E = 1
Faktor korosi : 1/16
Volume ruang kosong : 10% Volume total
Waktu tinggal : 3 hari
Jumlah *storage* : 4 buah
Kondisi
Suhu bahan : -103,7 ^{o}C = 169,45 K
Tekanan : 1 atm = 15 psia

Komponen	Massa kg/jam	Densitas (ρ) kg/m^3	xi	xi.ρi
C_2H_4	8770,8776	484,3881	0,998	483,613
H_2O	14,0071	62,1179	0,002	0,099
Total	8784,8847	546,51	1,000	483,712

(Perry's 8th, tabel 2-112 dan 2-30)

$$\rho \text{ campuran} = \frac{\Sigma xi.\rho i}{\Sigma xi}$$

$$= \frac{483{,}7125}{1{,}000} = 483{,}7 \text{ kg/m} = 30{,}1836597 \text{ lb/ft}^3$$

Rate masuk = 8784,8847 kg/jam = 19683,41276 lb/jam

Rate volumetrik = $\frac{19683,41276}{483,7125}$ = 40,6924 ft^3/jam

B. Menentukan volume liquida

Kapasitas C_2H_5OH = $\frac{\text{Kapasitas C2H4}}{\text{Jumlah storage yang digunakan}}$

= $\frac{19683,41276}{3}$

= 6561,137586 lb/jam

Rate volumetrik = $\frac{\text{Kapasitas } C_2H_5OH \text{ pada storage}}{\rho \quad C_2H_5OH}$

= $\frac{6561,137586 \text{ lb/jam}}{483,7125 \text{ lb/ft}^3}$

= 13,56412675 ft^3/jam

Volume liquida = Rate volumetrik x waktu tinggal

= 13,56412675 x 3 hari x 24 jam

= 976,6171259 ft^3

= 27,63826466 m^3

C. Menentukan volume tangki

Rumus : $V_T = V_L + V_{RK}$

Dimana : V_T = Volume tangki

V_L = Volume liquida

V_{RK} = Volume ruang kosong

- Untuk menentukan dimensi bejana, maka diasumsikan :
  - Volume ruang kosong = 10% volume tangki
  - Volume liquida = 90% volume tangki

Karena volume liquida 90% volume tangki maka, maka :

Volume tangki = $\frac{\text{Volume liquida}}{0,10}$

= $\frac{27,63826466}{10\%}$

= 276,3826466 ft^3 = 7,8216 m^3

D. Menentukan diameter tangki (di)

Volume tangki = $V_{silinder} + V_{tutup}$

276,3826466 = $\left(\frac{\pi}{4} di^2 \times Ls\right) + 0,0847\ di^3$

= $\left(\frac{\pi}{4} di^2 \times 1,5\ di\right) + 0,0847\ di^3$

276,3826466 = 1,2622 di^3

$di^3 = \frac{276,3826466}{1,2622}$

di^3 = 218,9689801

di = 5,036336953 ft

= 60,43604344 in

E. Menghitung tinggi liquida dalam tangki (L_{Is})

$V_{liquida} = \frac{\pi}{4} di^2 \times LIs$

13,56412675 = $\frac{3,14}{4}$ x 5,036336953 ^{2} x LIs

13,56412675 = 19,91128158 LIs

LIs = 0,681228212 ft

= 8,174738545 in

F. Menentukan tekanan design (P_{design})

Tekanan hidrostat = $\frac{\rho \times (H-1)}{144}$ (Brownell & Young pers 3,17 hal 46)

= $\frac{30,18365966 \text{ lb/ft}^3 \text{ X } 0,6812 \text{ ft} - 1}{144}$

= (0,0668) psia

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

= 14,7 + -0,0668

= 14,6332 psia
= 29,3332 psig

G. Menghitung tebal tangki (ts)

Diketahui : Data didapatkan dari Brownell hal 342

- Bahan kontruksi yang dipilih : Hygh alloy steel SA - 240 Grade M Type 316
- f = 18750 psi
- E = 0,8 Double welded butt joint
- C = 1/16
- $Ts = \frac{Pi.di}{2(f.E - 0,6Pi)} + C$

$= \frac{14,6332 \times 5,0363}{2\,(\,18750 \times 0,8 -)(\,0,6 \times \#\#\#\#\#\#\,)} + \frac{1}{16}$

$= \frac{73,6976}{29982,4402} + 1/16$

= 0,0025 + 1/16

= 0,062 in x $\frac{16}{16}$ = $\frac{1}{16}$ ung Table 5.7 hal 90)

H. Menentukan harga di(baru), Ls, icr, dan r

Standarisasi do

do = di (lama) + 2 ts
= 60,4360 + 2 x 1/16
= 60,4360 + 0,1250 0
= 60,5610 in

dari tabel 5.7 (Brownell hal. 90) didapatkan:

do (baru) = 66 in

di = do (baru - 2 ts
= 66 - 2 x 1/16
= 65,8750 in
= 5,4896 ft

Ls = 1,8 di
= 1,8 x 65,8750
= 118,5750 in

ha = 0,1690 di
= 0,1690 x 65,8750
= 11,1329 in

$tha = \frac{0,885 \times pi \times di}{(f \times E - 0.1pi)} + C$

$= \frac{0,8850 \times 14,6332 \times 65,8750}{(\,18750 \times 0,8 - 0,1 \times 14,6332\,)}$

$= \frac{853,1054}{14998,537}$

= 0,0569 = 1/16 in

Tinggi storage

H = Ls + ha
= 118,58 + 11,13
= 129,71 in
= 3,3127 m

Spesifikasi Alat Storage Etilene :

Nama = Storage etilene (tangki penyimpanan)
Type = Tangki berbentuk bola spherical
Bahan = Bagian dalam stelees steel SA - 240 Grade M Type 316

Dimensi Storage :

V_L	=	0,681228212	ft^3	Ls	=	118,6	in
di	=	5,4896	ft	V_T	=	276,4	ft^3
H	=	129,71	in	tha	=	1/16	in
Lis	=	0,681228212	ft	ha/hb	=	11,13	in