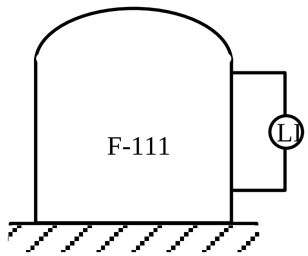
APPENDIKS C
SPESIFIKASI ALAT

1. Storage Tank Karbon Disulfida (F-111)

Fungsi : Untuk menyimpan bahan baku Karbon Disulfida

Tipe : Tangki bentuk silinder tegak dengan tutup atas berbentuk standard dished dan dasar berbentuk datar (flat bottom)



Direncanakan :

Bahan konstruksi = Carbon steels SA-135 Grade B

Allowable stress (f) = 12750

Tipe pengelasan = Double welded but joint (E = 0.8)

Faktor korosi (C) = 1/16 in

Waktu tinggal = 7 hari

Volume ruang kosong = 20% Volume total

Jumlah tangki = 2 buah

Kondisi operasi :

Suhu operasi = 30 ^oC = 303.15 K

Tekanan operasi = 1 atm = 14.7 psia

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
CS2	76	1.79680	0.28749	552.000	0.32260
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06

dimana, ρ dalam mol/m^3

$$\rho = \frac{C_1}{C_2^{(1 + (1 - \frac{T}{C_3})^{C_4}}}$$

untuk water mengunakan persamaan:

$$\rho = C_1 + C_2T + C_3T^2 + C_4T^3$$

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
CS2	3993.5055	0.9900	244.7348	242.2875
H_2O	40.33844	0.0100	998.7518	9.9875
Total	4033.844	1.0000	1243.4866	252.2750

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

$$= \frac{252.2750}{1.0000} = 252.2750 \text{ kg/m}^3 = 15.7420 \text{ lb/ft}^3$$

Rate Carbon Disulfide masuk (m) = 4033.84399 kg/jam
= 8893.0125 lb/jam

PERHITUNGAN

A. Menghitung Volume Tangki

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

$$= \frac{4033.844 \text{ kg/jam}}{252.2750 \text{ kg/m}^3} \times \frac{24 \text{ jam}}{1 \text{ hari}} \times 7 \text{ hari}$$

$$= 2686.2981 \text{ m}^3$$

Jumlah bahan baku Carbon Disulfide yang harus disimpan dalam 7 hari sebany
2686.2981 m^3 yang disimpan didalaı 2 buah tangki storage dimana
jika disimpan dalam 1 buah tangki akan membutuhkan volume yang terlalu bes
sehingga,

$$\text{Volume} = \frac{2686.2981}{2} = 1343.14903 \text{ m}^3$$

$$\text{Volume tangki} = \frac{1343.1490}{0.8} = 1678.93629 \text{ m}^3$$

B. Menentukan Dimensi tangki

Asumsi Ls = 1.5 di

Volume tanki = Volume silinder + Tutup atas

$$1678.9363 = \frac{\pi}{4} di^2 Ls + 0{,}0847\ di^3$$

$$1678.9363 = \frac{\pi}{4} di^2 \times 1{,}5di + 0{,}0847di^3$$

$$1678.9363 = 1.3034\ di^3$$

$$di^3 = 1288.1551$$

$$di = 10.8807 \text{ m} = 428.3735 \text{ in} = 35.6973 \text{ ft}$$

C. Menghitung Tinggi Liquida

Tinggi liquida(HL) = $\dfrac{\text{Volume liquida}}{\frac{1}{4}\pi \times di^2}$

$= \dfrac{1343.1490}{\frac{1}{4} \times 3.14 \times 10.8807^2}$

= 14.4525 m = 568.9957 in = 47.4157 ft

D. Menentukan Tekanan Design (Pi)

Tekanan hidrostatik (Ph) = $\dfrac{\rho\,(HL-1)}{144}$

$= \dfrac{15.7420 \times (47.4157 - 1)}{144}$

= 5.0741 psia

= 19.7741 psig

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

= 0.0 + 19.7741

= 19.7741 psig

= 1.3634 bar

E. Menghitung Tebal Silinder (ts)

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

$= \dfrac{19.7741 \times 428.3735}{2\ (12750 \times 0.8 - 0.6 \times 19.7741)} + \dfrac{1}{1}$

$= 0.478 \times \dfrac{16}{16}$

ts = $\dfrac{7.6476}{16}$ in ≈ $\dfrac{5}{16}$ in

do = di + 2(ts)

= 428.3735 + 2(1/3)

= 428.9985 in ≈ 240 in

Berdasarkan "Brownel and Young" tabel 5.7 hal 90, didapatkan :

icr = 14 7/16 in

r = 180 in

di_{baru} = do_{st} - 2ts

= 240 - 2(1/3)

= 239.375 in

= 19.9479 ft

F. Menghitung Tinggi Silinder (Ls)

Tinggi silinder = 1.5 × di
= 1.55 × 19.9479 ft
= 30.8993 ft
= 370.792 in

G. Menghitung Dimensi Tutup Atas Dan Tutup Bawah

Bentuk tutup atas adalah standar dish dan tutup bawah adalah flat, sehingga :

r = di_{baru}

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

$= \frac{0.885 \times 19.7741 \times 239.375}{2\ (\ 12750 \times 0.8 - 0.1 \times 19.7741\ )} + \frac{1}{1}$

$= 0.2679 \times \frac{16}{16}$

$= \frac{4.2862}{16} \approx 4/16$ in

Tinggi Tutup atas (ha) = 0.169 × di
= 0.169 × 239.3750 in
= 40.4544 in

H. Menghitung Tinggi Tangki (H)

Tinggi tangki (H) = Tinggi silinder + Tinggi tutup atas
= 370.79188 + 40.4544
= 411.2463 in
= 34.2705 ft

G. Desain Bagian Bawah Tangki

Untuk mempermudah pengelasan dan memperhitungkan terjadinya korosi, mal pada lantai (bottom) dipakai plat dengan tebal minimal 1/2 in. Tegangan yang bekerja pada plat yang digunakan pada lantai harus diperiksa agar diketahui apakah plat yang digunakan telah memenuhi persyaratan atau tidak.

Tegangan yang bekerja pada bottom:

1. Compressive stress yang dihasilkan oleh carbon disulfide.

$S_1 = \frac{\sum liquid\ wt}{12\ \pi D_m (t_s - c)}$ (Brownell,1959. Pers.9-5 Hal 157

Dimana:

ts : tebal shell, in
Dm : diameter shell, ft
liquid wt dalam lb

$S_1 = \frac{8893.0125}{\quad}$

12 × 3.14 × 19.9479 (5/16 - 1/16)

S_1 = 47.3261 psi

2. Compressive stress yang dihasilkan oleh berat shell.

$$S_2 = \frac{X\rho_s}{144}$$ (Brownell,1959. Pers.9-3 Hal 156

Dimana:

X : tinggi tangki, ft

ρ_s : densitas material shel 490 lb/ft^3 untuk material steel

$$S_2 = \frac{34.2705 \times 490}{144}$$

= 116.61 psi

Tegangan total yang bekerja pada lantai:

$S_t = S_1 + S_2$

= 47.3261 + 116.61497

= 163.9410 psi

Batas tegangan lantai yang diizinkan:

$S_t < f.E$

163.9410 < 12750 × 0.8

163.9410 < 10200 sehingga memenuhi

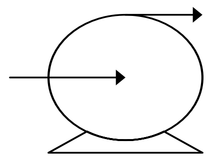
Spesifikasi Storage Tank Karbon Disulfida

Fungsi	:	Untuk menyimpan bahan baku Carbon Disulfide
Kode alat	:	F-111
Tipe	:	Silinder tegak dengan tutup bawah berbentuk flat bottom dan tutup atas berbentuk standard dished
Kapasitas	:	1678.9363 m^3
Suhu operasi	:	303.15 K
Tekanan operasi	:	1 atm
Dimensi		
Diameter shell	:	20.0000 ft
Tinggi shell	:	30.8993 ft
Tebal shell	:	1/3 in
Tinggi atap	:	3.3712 ft
Tebal atap	:	1/4 in
Tipe pengelasan	:	Double welded but joint (E = 0.8)
Bahan Konstruksi	:	Carbon steel SA-135 Grade B
Jumlah	:	2 buah

2. Pompa sentrifugal (L-112)

Fungsi : Untuk mengalirkan Carbon Disulfide dari storage tank (F-111) menuju vaporizer (V-113)

Tipe : Centrifugal pump



Direncanakan :

Bahan konstruksi = Carbon steel

Jumlah = 1 buah

Kondisi operasi :

Suhu (T) = 30 ^oC = 303.15 K

Tekanan (P) = 1 atm = 14.7 psia

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
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H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06

dimana, ρ dalam mol/m^3

$$\rho = \frac{C_1}{C_2^{(1+(1-\frac{T}{C_3})^{C_4})}}$$

untuk water mengunakan persamaan:

$$\rho = C_1 + C_2 T + C_3 T^2 + C_4 T^3$$

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
CS2	3993.5055	0.9900	244.7348	242.2875
H_2O	40.33844	0.0100	998.7518	9.9875
Total	4033.844	1.0000	1243.4866	252.2750

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

$$= \frac{252.2750}{1.0000} = 252.2750 \ kg/m^3 = 15.7420 \ lb/ft^3$$

Dari Perry 8th Edition tabel 2-313 Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5

Komponen	C1	C2	C3	C4	C5
CS2	-10.30600	703.01000			
H_2O	-52.84300	3703.6000	5.8660	-5.9.E-29	10

dimana μ dalam Pa.s

$$\mu = \exp(C1 + C2/T + C3\ln T + C4T^{C5}$$

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
CS2	3993.5055	0.9900	0.0003	0.0002	0.000226
H_2O	40.33844	0.0100	0.0008	0.0006	0.000006
Total	4033.844	1.0000	0.0012	0.0008	0.000232

μ campuran = $\frac{\sum xi.\mu i}{\sum xi}$

= $\frac{0.000232}{1.0000}$ = 0.000232 lb/ft.s = 0.833752 lb/ft.jam

Rate aliran = 4033.8 kg/jam = 8893.0125 lb/jam

PERHITUNGAN :

A. Menghitung Rate Volumetrik (Q)

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

= $\frac{8893.0125}{15.7420}$

= 564.9241 ft^3/jam

= 0.1569 ft^3/s

= 70.4327 gpm

Di $_{optimum}$ = 3,9 $Q^{0,45}$ × $\rho^{0,13}$ (Pers.15 "Petters&Timmerhaus",hal 496)

= 3.9 × 0.1569^{45} × $15.7420^{0,13}$

= 2.4252 ≈ 2 1/2 in

= 0.2083 ft

Untuk pipa ukuran 2 1/2 in sch 40

Dari Brownell and Young, App.K-2 Hal.387 didapatkan:

OD = 2.875 in = 0.2396 ft

ID = 2.469 in = 0.2058 ft

A = 0.03322 ft^2

B. Menentukan Kecepatan Aliran Fluida (v)

Kecepatan aliran fluic = $\frac{Q}{A}$

$$= \frac{564.9241}{0.03322}$$

= 17005.5429 ft/jam

= 4.7238 ft/s

C. Menentukan Bilangan Reynold

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

$$= \frac{0.20575 \times 4.7238 \times 15.7420}{0.000232}$$

= 66062.071 $\geq$ 4000 (aliran turbulen)

DariGeankoplis, Fig. 2.10-3 Hal. 88 didapatkan:

Equivalent rougness (ε) = 4.6E-05 m

Relative rougness $\frac{\varepsilon}{D}$ = 0.0007

Faktor friksi (f) = 0.007

α = 1

D. Menentukan Panjang Pipa

Asumsi :

- Panjang pipa lurus = 150 ft
- elbow 90^o = 2 buah

  Le/D = 35 (Geankoplis,Tabel 2-10.1 Hal 93)

  L elbow = 35 ID

  = 35 × 2 × 0.23958 ft

  = 16.771 ft
- Globe valve = 1 buah

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

  L elbow = 300 ID

  = 300 × 1 × 0.23958 ft

  = 71.875 ft

Panjang pipa total (L) = Pipa lurus + elbow 90^o + globe valve

= 150 + 16.771 + 71.875

= 238.646 ft

= 2864 in

E. Menentukan friksion Loss

1. Friksi pada pipa lurus

$F_f = 4f \, \underline{\Delta L} \times \underline{v^2}$ (Geankoplis, Pers.2-10.6 Hal 86)

$$= 4 \times 0.0070 \; \frac{238.6458}{0.20575} \times \frac{4.7238^2}{2 \times 32.2}$$

(D, $2g_c$)

= 11.2619 lbf.ft/lbm

2. Kontraksi pada keluaran tangki

$$hc = Kc \frac{v^2}{2g_c}$$ (Geankoplis, Pers.2-10.16 Hal 93)

$$= 0.55 \; \frac{4.7238^2}{2 \times 32.174}$$

= 0.1907 lbf.ft/lbm

3. Elbow 90°, 2 buah

K_f = 0.75 (Geankoplis, Tabel 2.10-1 Hal. 93

$$hf = 2Kf \frac{v^2}{2g_c}$$ (Geankoplis, Pers.2-10.17 Hal 94)

$$= 2 \times 0.75 \; \frac{4.7238^2}{2 \times 32.174}$$

= 0.5202 lbf.ft/lbm

Total friksi (∑F) = 11.2619 + 0.1907 + 0.520154
= 11.9728 lbf.ft/lbm

F. Menentukan Kesetimbangan Mekanik

Direncanakan:

ΔZ = 30 ft

ΔP = 0 lb/ft^2

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

v_2 = 4.724 ft/s

α = 1 (aliran turbulen)

Sehingga Mechanical energy balance :

$$\frac{V_2 - V_1}{2.\alpha.gc} + \Delta Z\frac{g}{gc} + \frac{\Delta P}{\rho} + \sum F = -Ws$$

$$\frac{4.7238 - 0}{2 \times 1 \times 32.17} + 30 \; \frac{32.17}{32.17} + 11.9728 = -Ws$$

-Ws = 42.0462 lbf.ft/lbm

Dengan: Capacity = 70.4327 gal/menit
μ campuran = 1.1595 Centipoise

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

Efisiensi pompa (η) = 90%

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

$$42.0462 = -\ 90\%\ Wp$$

$$Wp = 46.7180\ \text{ft.lbf/lbm}$$

mass flow rate (m) = Q x ρ

$$= 564.9241 \times 15.7420$$

$$= 8893.0125\ \text{lbm/jam}$$

$$= 2.4703\ \text{lbm/s}$$

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

$$WHp = 46.7180 \times 2.4703 \times \frac{1\ \text{hp}}{550\ \text{ft.lbf/s}}$$

$$WHp = 0.2098\ \text{hp}$$

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

$$= \frac{0.2098}{90\%}$$

$$= 0.2331\ \text{Hp}$$

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

Efisiensi motor = 90%

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

$$= \frac{0.2331}{90\%}$$

$$= 0.2590\ \text{Hp} \approx 1\ \text{Hp}$$

Spesifikasi Pompa Sentrifugal

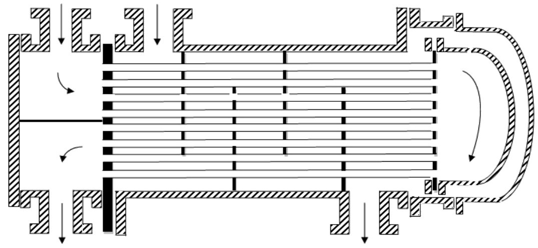
Fungsi	:	Untuk mengalirkan Carbon Disulfide dari storage (F-111) menuju vaporizer (V-113)
Kode alat	:	L-112
Tipe	:	Centrifugal pump
Kapasitas	:	70.4327 gpm
Suhu operasi	:	303.15 K
Tekanan operasi	:	1 atm
Efisiensi Pompa	:	90%
ΔP	:	0 lb/ft^2
Bahan Konstruksi	:	Carbon steel
Daya	:	1 Hp
Dimensi		

NPS	:	3	in	OD	:	2.875	in	A	:	0.03322 ft^2
Sch	:	40		ID	:	2.469	in			

3. Vaporizer (V-113)

Fungsi : Untuk menguapkan carbon disulfide liquid menjadi vapor

Tipe : Shell and Tube Heat Exchanger



Direncanakan :

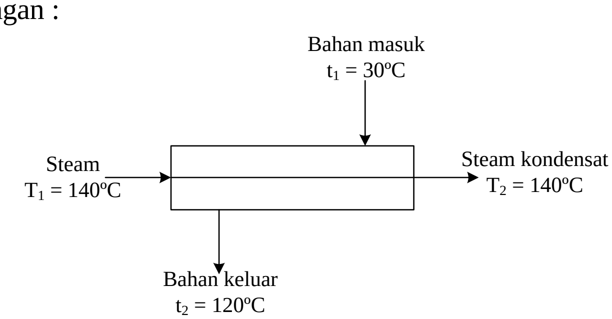
- faktor kekotoran gabungan minumum (Rd) = 0.004 jam.ft^2.^{o}F/Btu
- Δp maksimum aliran = 10 psi
- Δp maksimum steam = 2.5 psi

Dasar perencanaan :

Dari Appendix B didapatkan data sebagai berikut:

- Massa bahan masuk = 4,033.8440 kg/jam
  = 8,893.0125 Ib/jam
- Suhu bahan masuk (t_1) = 30 ^{o}C = 86.00 ^{o}F
- Suhu bahan keluar (t_2) = 120 ^{o}C = 248 ^{o}F
- Kebutuhan steam (m) = 108.8224 kg/jam
  = 239.9098 Ib/jam
- Panas yang dibawa steam = 55,763.6562 kkal/jam
  = 221,143.9411 btu/jam
- Steam masuk pada suhu(T_1) = 140 ^{o}C = 284 ^{o}F = 413.15 K
- Steam keluar pada suhu (T_2) = 140 ^{o}C = 284 ^{o}F = 413.15 K
- Digunakan pipa ukuran 3/4 in OD, BWG 16, L = 12 ft, P_T = 1 in
- Shell side : Carbon Disulfide
- Tube side : Steam
- Susunan tube segitiga (triangular pitch)

Perhitungan :



A. Menghitung ΔT_{LMTD}

Δt_1 = $T_1 - t_2$ = 284 ^{o}F - 248 ^{o}F = 36 ^{o}F

Δt_2 = $T_2 - t_1$ = 284 ^{o}F - 86.00 ^{o}F = 198 ^{o}F

$\Delta T_{LMTD} = \frac{\Delta t_1 - \Delta t_2}{\ldots}$ (Kern, Pers.5.14 Hal.89

ΔT_{LMTD} = $\frac{}{\ln \Delta t_1/\Delta t_2}$

$= \frac{36 - 198.00}{\ln(36 / 198.00)}$

= 95.0287 °F

B. Menghitung Suhu Kalorik (Tc dan tc)

$T_c = (T_1 + T_2) / 2$ = 284 °F = 140 °C = 413.15 K

$t_c = (t_1 + t_2) / 2$ = 167 °F = 75 °C = 348.15 K

C. Trial U_D

Dari Kern hal 840 tabel 8 diperoleh:

Range U_D = 100-200 Btu/jam ft^2. °F

Dicoba U_D = 100 Btu/jam ft^2. °F

Dari App.B didapatkan Q = 55,763.656 kkal/jam

= 2212878.6 Btu/jam

$$A = \frac{Q}{U_D \cdot \Delta t} = \frac{2212878.6246}{100 \times 95.0287} = 232.8642 \ ft^2$$

dengan,

do_{tube} = 3/4 in

BWG = 16

Dari Kern, tabel 10, hal. 843, diperoleh harga a" = 0.1963 ft^2/ft

$$Nt = \frac{A}{a'' \cdot L} = \frac{232.8642}{0.1963 \times 12} = 99 \text{ buah}$$

Dari Kern, tabel 9, hal. 842, diperoleh :

IDs = 13 1/4 in

n = 4

Nt = 86

$$U_D \text{ koreksi} = \frac{Nt}{Nt \text{ standar}} \times U_D \text{ trial}$$

$$= \frac{99}{86} \times 100 = 115.1 \text{ Btu/jam ft}^2 \cdot {}^oF$$

Dari Kern, tabel 28, hal. 838, diperoleh :

de = 0.73 in

Viskositas aliran pada shell (bahan):

Dari Perry 8th Edition tabel 2-313 Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
CS2	-10.30600	703.010			

H_2O	-52.84300	3703.600	5.8660	-5.9.E-29	10

dimana μ dalam Pa.s

$$\mu = \exp(C1 + C2/T + C3 \ln T + C4T^{C5}$$

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
CS2	3993.5055	0.9900	0.00025	0.0002	0.000168
H_2O	40.33844	0.0100	0.00038	0.0003	0.000003
Total	4033.844	1.0000	0.00063	0.0004	0.000170

$$\mu \text{ campuran} = \frac{\sum xi.\mu i}{\sum xi} = \frac{0.000170}{1.0000} = 0.000170 \text{ lb/ft.s} = 0.61232 \text{ lb/ft.jam}$$

Viskositas aliran pada tube(steam):

Dari Perry 8th Edition tabel 2-313 Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
H_2O	-52.84300	3703.6000	5.8660	-5.9.E-29	10

dimana μ dalam Pa.s

$$\mu = \exp(C1 + C2/T + C3 \ln T + C4T^{C5}$$

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
H_2O (steam)	108.8224	1.0000	0.000193	0.000130	0.000130

Kesimpulan sementara hasil perancangan :

Type HE : 2-4

Bagian *Tube*

- do = 3/4 in, 16 BWG
- L = 12 ft Nt = 86
- Susunan segitiga, n = 4
- di = 0.6200 in = 0.052 ft
- a' = 0.3020 in^2 = 0.025 ft^2
- a" = 0.1963 ft^2/ft
- Pt = 1 in

Bagian *Shell*

- IDs = 13 1/4 in = 1.1 ft
- n' = 2
- B = 4 in = 0.33 ft
- de = 0.73 in = 0.06 ft
- C' = 1 - 3/4 = 1/4

Evaluasi Perpindahan Panas

Hot fluid: tube, Steam	Cold fluid: shell, Carbon disulfide
	Preheating:
1. Menghitung NRe	1'. Menghitung NRe
$a_t = \dfrac{Nt \times a'}{n \times 144}$	$a_s = \dfrac{IDs \times C' \times B}{n' \times Pt \times 144}$

$= \frac{86 \times 0.025}{4 \times 144}$

$= 0.0038 \ ft^2$

$G_t = \frac{m}{a_t}$

$= \frac{239.9098 \ lb/jam}{0.0038 \ ft^2}$

$= 63847.8600 \ lb/jam.ft^2$

pada Tc = 284 ^oF

μ = 0.000130 lb/ft.s

= 0.467479 lb/ft.jam

di = 0.62 in

= 0.052 ft

$N_{re} = \frac{G_t \times di}{\mu}$

$= \frac{63847.8600 \times 0.62}{0.467479}$

= 84679.0

$= \frac{13.25 \times 0.25 \times 4}{2 \times 1 \times 144}$

$= 0.04601 \ ft^2$

$G_s = \frac{M}{a_s}$

$= \frac{8893.0125 \ lb/jam}{0.0460 \ ft^2}$

$= 193297.1763 \ lb/jam.ft^2$

pada tc = 167 ^oF

μ = 0.00017 lb/ft.s

= 0.61232 lb/ft.jam

de = 0.73 in

= 0.06 ft

$Nre_s = \frac{G_{an} \times de}{\mu}$

$= \frac{193297.1763 \times 0.06}{0.6123}$

= 19203.8634

2. J_H = - (*steam*)

2'. Menghitung faktor panas (J_H)

Dari Kern, Fig. 28Hal.838 didapatkan:

J_H = 90

3. Menghitung harga koefisien film perpindahan panas

untuk steam didapatkan:

h_{io} = 1500 Btu/ft^2.jam^{0}F

3'. Menghitung harga koefisien film

Dari Kern, Tabel 4 hal.800 didapatkan:

k = 0.093 Btu/jam.ft^2.^{o}F/ft

Dari Kern, Fig.2 hal.804 didapatkan:

Cp = 0.239 Btu/lb.^{o}F

maka,

$k (Cp.\mu /k)^{1/3}$ = 0.1081

ho/φs = 159.97

tw = 178.28 ^oF

dimana μ Pada suhu tw didapatkan:

μw = 0.5850 lb/ft.jam

μ /μw = 1.05

Dari Kern, Fig. 24 Hal.834 didapatkan:

φs = 1.006

sehingga,

ho = 160.994 Btu/jam.ft^{2o}F

Clean overall coefficient untuk preheating U_p :

$$U_p = \frac{hio \cdot ho}{hio + ho} = \frac{1500 \times 160.994}{1500 + 160.994} = 321.988 \ \text{Btu/ft}^2.\text{jam}^0\text{F}$$

Clean surface yang dibutuhkan untuk preheating A_p :

Dari App.B didapatkan q_p = 58334.554 kkal/jam = 2314900.01 Btu/jam

$$A_p = \frac{q_p}{U_p \Delta T_{LMTD}} = \frac{2314900.01}{321.99 \times 95.0287} = 75.65499 \ \text{ft}^2$$

Vaporization:

1'. Menghitung NRe

Pada suhu 248 ^oF

Dari Kern, Fig. 15 Hal.825 didapatkan:

μ = 0.1800 cp
= 0.435436 lb/ft.jam

de = 0.73 in
= 0.06 ft

$$Nre_s = \frac{G_s \times de}{\mu}$$

$$= \frac{193297.1763 \times 0.06}{0.4354}$$

= 27004.9201

2'. Menghitung faktor panas (J_H)

Dari Kern, Fig. 24 Hal.834 didapatkan:

J_H = 97

3'. Menghitung harga koefisien film

Dari Kern,Tabel 4 hal.800 didapatkan:

k = 0.093 Btu/jam.ft^2.^{o}F/ft

Dari Kern,Fig.2 hal.804 didapatkan:

Cp = 0.219 Btu/lb.^{o}F

maka,

$k\,(Cp.\mu/k)^{1/3}$ = 0.0937

ho/φs = 149.44

tw = 177.6 ^oF

dimana μ Pada suhu tw didapatkan:

μw = 0.58624 lb/ft.jam

μ /μw = 0.74

Dari Kern, Fig. 24 Hal.834 didapatkan:

φs = 0.959

sehingga,

$ho = 143.349$ Btu/jam.ft^{2o}F

Clean overall coefficient untuk Vaporization U_v :

$$U_v = \frac{hio \cdot ho}{hio + ho} = \frac{1500 \times 143.349}{1500 + 143.349} = 286.70 \text{ Btu/ft}^2\text{.jam}^0\text{F}$$

Clean surface yang dibutuhkan untuk preheating A_v:

Dari App.B didapatkan q_v = 58692.35 kkal/jam = 2329098.48 Btu/jam

$$A_v = \frac{q_p}{U_v \, \Delta T_{LMTD}} = \frac{2329098.478}{286.7 \times 95.0287} = 85.48848 \text{ ft}^2$$

Total clean surface A_c :

$$Ac = A_p + A_v = 75.655 + 85.488 = 161.1435 \text{ ft}^2$$

Weighted clean overall coefficient Uc :

$$Uc = \frac{\sum UA}{Ac} = \frac{24360 + 24509}{161.14} = 303.2666$$

Menghitung overall coefficient :

surface per lin ft tube (a") = 0.1963 ft^2/ft

Total surface = Nt x L x a"

= 86 × 12 × 0.1963

= 202.58 ft^2

$$U_D = \frac{Q}{A \cdot \Delta t} = \frac{2212878.6246}{202.58 \times 95.0287} = 114.948364$$

Check maksimum fluks :

Total surface area yang dibutuhkan = 161.1435 ft^2

Surface area yang dibutuhkan untuk vaporisasi = 85.48848 ft^2

Total surface area yang tersedia = 202.5816 ft^2

Sehingga dapat diasumsikan bahwa,

surface area yang tersedia untuk vaporisasi $= \frac{85.48848}{161.1435} \times 202.58 \text{ ft}^2$

$= 107.4719 \text{ ft}^2$

Dirt factor :

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

$$= \frac{303.26659 - 115}{303.26659 \times 115} = 0.0054 \text{ jam.ft}^2\text{.°F/Btu}$$

Karena harga Rd hitung > Rd tetapan, maka rancangan HE memenuhi.

Evaluasi ΔP

Hot fluid: tube, Steam

1. Pada NRe_t = 84679.0061
   Dari Kern,fig. 26 hal.836,
   diperoleh: f = 0.00013

   Dari steam tabel, untuk kondisi :
   saturated steam
   T = 284 °F
   P = 45.4 psia
   didapatkan,
   specific vol. = 9.3197 ft^3/lb

   $$sg = \frac{1}{9.3197 \times 62.5} = 0.002$$

2. ΔP karena panjang pipa :

$$\Delta Pl = \frac{1}{2} \cdot \frac{f.Gt^2.L.n}{5,22\times10^{10}.di.sg.\phi}$$

$$= \frac{0.00013 \times \#\#\#\#\#\#\#\#^2 \times 12 \times 4}{2 \times 5,22.10^{10} \times 0.052 \times 0.002 \times 1}$$

= 2.8319 psi

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

$$\left[\frac{v^2}{2gc}\right]\frac{\rho}{144} = 7E-05$$, sehingga

$$\Delta Pn = \frac{4n}{sg}\left[\frac{v^2}{2gc}\right]\frac{\rho}{144}$$

$$= \frac{4 \times 4}{0.0017} \times 0.00007$$

= 0.6524 psi

sehingga,
ΔPt total = 2.8319 + 0.6524
= 3.48 psi < 2.5 psi
desain memenuhi

Cold fluid: shell, Carbon disulfide

Preheating:

1'. Pada Nres = 19203.8634
Dari Kern,fig. 29 hal.839, diperoleh:
f = 0.003

2'. Panjang area preheating

$$L_p = \frac{L.A_p}{A_c} = \frac{12 \times 75.65499}{161.1434677} = 5.6339 \text{ ft}$$

3'. No. of crosess

$$(N+1) = \frac{12Lp}{B} = \frac{12 \times 5.6339}{4} = 16.9$$

Dari Kern,Tabel 6 hal.808, diperoleh:
sg = 1.26

4'. $$\Delta Ps = \frac{f.Gs^2.IDs.(N+1)}{5,22\times10^{10}.de.sg.\phi}$$

$$= \frac{0.003 \times 193297.18^2 \times 1 \times 17}{5,22\times10^{10} \times 0.06083 \times 1.26 \times 0.97}$$

= 4.67124 psi

Vaporization:

1'. Pada Nres = 27004.9201
Dari Kern,fig. 29 hal.839, diperoleh:
f = 0.002

2'. Panjang area vaporization

$$L_v = \frac{L.A_v}{A_c} = \frac{12 \times 85.48848}{161.1434677} = 6.3661 \text{ ft}$$

3'. No. of crosess

$(N+1) = \frac{12Lv}{B} = \frac{12 \times 6.3661}{4}$

= 19.1

Dari Kern,Tabel 6 hal.808, diperoleh:

sg = 1.26

4'. $\Delta Ps = \frac{f.Gs^2.IDs.(N+1)}{5{,}22\times10^{10}.de.sg.\phi}$

$= \frac{0.002 \times 193297.18^2 \times 1 \times 19}{5{,}22\times10^{10} \times 0.06083 \times 1.26 \times 0.97}$

= 4.26332 psi

sehingga,

ΔPs total = 4.671238 + 4.2633

= 8.934558 psi < 10 psi

desain memenuhi

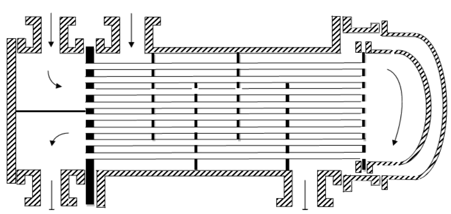
Spesifikasi Vaporizer

Fungsi	:	Untuk menguapkan carbon disulfide liquid menjadi vapor
Kode alat	:	V-113
Tipe	:	Shell and Tube Heat Exchanger 2-4
Bahan Konstruksi	:	Carbon steel SA-135 Grade B
Media pemanas	:	Saturated steam 140 ^oC , 361.379 kPa
Kapasitas	:	4,033.8440 kg/jam = 8,893.0125 lb/jam
Rate steam	:	108.8224 kg/jam = 239.9098 lb/jam
Dimensi		*Tube side* , steam — *Shell side* , Carbon Disulfide
		do = 3/4 in 16 BWG — IDs = 13 1/4 in = 1.1
		di = 0.62 in — B = 4 in
		L = 12 ft — de = 0.73 in
		Nt = 86 — C' = 0.25 in
		Pt = 1 in — ΔPs = 8.93 psi
		Tringular Pitch
		ΔPt = 3.48 psi

4. Heater (E-114)

Fungsi : Untuk memanaskan Klorin

Tipe : Shell and Tube Heat Exchanger



Direncanakan :

- faktor kekotoran gabungan minumum (Rd) = 0.004 jam.ft^2.°F/Btu
- Δp maksimum aliran = 10 psi
- Δp maksimum steam = 2.5 psi

Dasar perencangan :

Dari Appendix B didapatkan data sebagai berikut:

- Massa bahan masuk = 11305.38 kg/jam
  = 24,923.838 Ib/jam
- Suhu bahan masuk (t_1) = 28.6 °C = 83.43 °F
- Suhu bahan keluar (t_2) = 120 °C = 248 °F
- Kebutuhan steam (m) = 237.3149 kg/jam
  = 523.1844 Ib/jam
- Panas yang dibawa steam = 121,606.8429 kkal/jam
  = 482,260.6398 btu/jam
- Steam masuk pada suhu(T_1) = 140 °C = 284 °F = 413.15 K
- Steam keluar pada suhu (T_2) = 140 °C = 284 °F = 413.15 K
- Digunakan pipa ukuran 3/4 in OD, BWG 16, L = 12 ft, P_T = 1 in
- Shell side : Klorin
- Tube side : Steam
- Susunan tube segitiga (triangular pitch)

Perhitungan :

A. Menghitung ΔT_{LMTD}

$\Delta t_1 = T_1 - t_2$ = 413 °F - 248 °F = 165 °F

$\Delta t_2 = T_2 - t_1$ = 413 °F - 83.43 °F = 330 °F

$$\Delta T_{LMTD} = \frac{\Delta t_1 - \Delta t_2}{\ln \Delta t_1/\Delta t_2}$$ (Kern, Pers.5.14 Hal.89

$$= \frac{165 - 329.72}{\ln(165 / 329.72)}$$

= 238.03 °F

$$R = \frac{T_1 - T_2}{t_2 - t_1} = \frac{413 - 413}{248 - 83.4} = 0.00$$ (Kern, pers. 5.14 hal 14

$$S = \frac{t_2 - t_1}{T_1 - t_1} = \frac{248 - 83.4}{413 - 83.4} = 0.50$$

Jadi,

Ft = 1 (Isotermal) *(Kern, hal 167)*

Sehingga Tipe HE; 2-4

$\Delta t = \Delta T_{LMTD} \times Ft$ = 238.0294 = 238.03 °F

B. Menghitung suhu kalorik

Tc = (T_1 + T_2) / 2 = 284 ^oF = 140 ^oC = 413.15 K

tc = (t_1 + t_2) / 2 = 166 ^oF = 74.3 ^oC = 347.435 K

C. Trial U_D

Dari Kern hal 840 tabel 8 diperoleh:

Range U_D = 200-700 Btu/jam ft^2. ^oF

Dicoba U_D = 200 Btu/jam ft^2. ^oF

Dari App.B didapatkan Q = 121606.84 kkal/jam

= 4825745 Btu/jam

$$A = \frac{Q}{U_D \cdot \Delta t} = \frac{4825744.9697}{200 \times 238.0294} = 506.8434 \ ft^2$$

dengan,

do tube = 3/4 in

BWG = 16

Dari Kern, tabel 10, hal. 843, diperoleh harga a" = 0.1963 ft^2/ft

$$Nt = \frac{A}{a'' \cdot L} = \frac{506.8434}{0.1963 \times 12} = 215 \ \text{buah}$$

Dari Kern, tabel 9, hal. 842, diperoleh :

IDs = 17 1/4 in

n = 4

Nt = 178

$$U_D \text{ koreksi} = \frac{Nt}{Nt \text{ standar}} \times U_D \text{ trial}$$

$$= \frac{215}{178} \times 200 = 241.76 \ \text{Btu/jam ft}^2 \cdot {}^oF$$

Dari Kern, tabel 28, hal. 838, diperoleh :

de = 0.72 in

Viskositas aliran pada shell (bahan):

Dari Perry 8th Edition tabel 2-312 Hal. 2-421didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
Cl2	2.60E-07	0.7423	98.3		
CO2	2.15E-06	0.46	290		

dimana μ dalam Pa.s

$$\mu = \frac{C_1 T^{C2}}{1 + C_3/T + C_4/T^2}$$

Komponen	Massa	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi

Komponen	(Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
Cl2	11192.325	0.9900	0.00078	0.0005	0.000516
CO2	113.05379	0.0100	0.01986	0.0133	0.000133
Total	11305.379	1.0000		0.0139	0.000650

$$\mu \text{ campuran} = \frac{\sum xi.\mu i}{\sum xi}$$

$$= \frac{0.000650}{1.0000} = 0.000650 \text{ lb/ft.s} = 2.338697 \text{ lb/ft.jam}$$

Viskositas aliran pada pipe (steam):

Dari Perry 8th Edition tabel 2-312 Hal. 2-421didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
H_2O	1.710.E-08	1.1146			

dimana μ dalam Pa.s

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
H_2O (steam)	140.0000	1.0000	2.E-06	0.000001	0.000001

Kesimpulan sementara hasil perancangan :

Type HE : 2-4

Bagian *Tube*		Bagian *Shell*	
do	= 3/4 in, 16 BWG	IDs	= 17 1/4 in = 1.44 ft
L	= 12 ft Nt = 178	n'	= 2
Susunan segitiga, n = 4		B	= 4 in = 0.33 ft
di	= 0.6200 in = 0.052 ft	de	= 0.72 in = 0.06 ft
a'	= 0.3020 in^2 = 0.025 ft^2	C'	= 1 1/4 - 1 = 0.25
a"	= 0.1963 ft^2/ft		
Pt	= 1 in		

Evaluasi Perpindahan Panas

Hot fluid: tube, Steam	Cold fluid: shell, gas klorin
1. Menghitung NRe	1'. Menghitung NRe
$a_t = \frac{Nt \times a'}{n \times 144}$	$a_s = \frac{IDs \times C' \times B}{n' \times Pt \times 144}$
$= \frac{178 \times 0.025}{178 \times 144}$	$= \frac{1.438 \times 0.25 \times 4}{2 \times 1 \times 144}$
$= 0.0002 \ ft^2$	$= 0.00499 \ ft^2$
$G_t = \frac{m}{a_t}$	$G_s = \frac{M}{a_s}$
$= \frac{523.1844 \text{ lb/jam}}{0.0002 \ ft^2}$	$= \frac{24923.838 \text{ lb/jam}}{0.0050 \ ft^2}$
= ########## $lb/jam.ft^2$	= 4993436.6672 $lb/jam.ft^2$

pada Tc = 284 ^oF

μ = 0.000001 lb/ft.s

= 0.004389 lb/ft.jam

di = 0.62 in

= 0.052 ft

$N_{re} = \frac{G_t \times di}{\mu}$

= $\frac{\text{##########} \times 0.052}{0.004389}$

= 35241336.4

2. J_H = - (*steam*)

3. Menghitung harga koefisien film perpindahan panas

untuk steam didapatkan:

h_{io} = 1500 Btu/ft^2.jam^{0}F

pada tc = 166 ^oF

μ = 0.000650 lb/ft.s

= 2.33870 lb/ft.jam

de = 0.72 in

= 0.06 ft

$Nre_s = \frac{G_{an} \times de}{\mu}$

= $\frac{4993436.6672 \times 0.06}{2.33870}$

= 128108.1605

2'. Menghitung faktor panas (J_H)

Dari Kern, Fig. 24 Hal.834 didapatkan:

J_H = 1100

3'. Menghitung harga koefisien film

Dari Kern, Tabel 4 hal.800 didapatkan:

k = 0.043 Btu/jam.ft^2.^{o}F/ft

Dari Kern, Fig.3 hal.805 didapatkan:

Cp = 0.131 Btu/lb.^{o}F

maka,

$k\,(Cp.\mu/k)^{1/3}$ = 0.0827

ho/φs = 1516.17

tw = 225.81 ^oF

dimana μ Pada suhu tw didapatkan:

μw = 0.5086 lb/ft.jam

$\mu/\mu w$ = 4.6

Dari Kern, Fig. 24 Hal.834 didapatkan:

φs = 1.238

sehingga,

ho = 1877.183 Btu/jam.ft^{2o}F

Clean overall coefficient Uc :

$$U_c = \frac{hio \cdot ho}{hio + ho} = \frac{1500 \times 1877.183}{1500 + 1877.183} = 3754.37 \text{ Btu/ft}^2\text{.jam}^0\text{F}$$

Dirt factor (faktor kekotoran) pipa terpakai

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

$$= \frac{3754.36550 - 242}{3754.3655 \times 242} = 0.00387 \text{ jam.ft}^2\text{.°F/Btu}$$

Karena harga Rd hitung > Rd tetapan, maka rancangan HE memenuhi.

Evaluasi ΔP

Hot fluid: tube, Steam

1. Pada NRe_t = 35241336.4436

Dari Kern,fig. 26 hal.836,
diperoleh : f = 0.00019

Dari steam tabel, untuk kondisi :
saturated steam
T = 284 °F
P = 45.4 psia
didapatkan,
specific vol. = 9.3197 ft^3/lb

$$sg = \frac{1}{9.3197 \times 62.5}$$
= 0.0017

2. ΔP karena panjang pipa :

$$\Delta Pl = \frac{1}{2} \cdot \frac{f.Gt^2.L.n}{5{,}22 \times 10^{10}.di.sg.\phi}$$

$$= \frac{0.00019 \times \#\#\#\#\#\#\#\#^2 \times 12 \times 4}{2 \times 5{,}22.10^{10} \times 0.052 \times 0.002 \times 1}$$

= 3.5303 psi

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

$$\left[\frac{v^2}{2gc}\right]\frac{\rho}{144} = 0.55$$
, sehingga

$$\Delta Pn = \frac{4n}{sg}\left[\frac{v^2}{2gc}\right]\frac{\rho}{144}$$

$$= \frac{4 \times 4}{0.0017} \times 0.55$$

= 0.5126 psi

sehingga,
ΔPt total = 3.5303 + 0.5126
= 4.04 psi > 2.5 psi
desain memenuhi

Cold fluid: shell, gas Klorin

1'. Pada Nres = 128108.1605

Dari Kern,fig. 29 hal.839, diperoleh:
f = 0.0008

2'. No. of crosess

$$(N+1) = \frac{12L}{B} = \frac{12 \times 12}{4}$$
= 36

Dari Kern,Tabel 6 hal.808, diperoleh:
sg = 1.29

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

$$= \frac{0.001 \times 4993436.7^2 \times 1.44 \times 36}{5{,}22 \times 10^{10} \times 0.06 \times 1.29 \times 0.97}$$

= 13.17 psi > 10.0 psi
desain memenuhi

Spesifikasi Heater

Fungsi	: Untuk memanaskan gas klorin

Kode alat	:	E-114
Tipe	:	Shell and Tube Heat Exchanger 2-4
Bahan Konstruksi	:	Carbon steel SA-135 Grade B
Media pemanas	:	Saturated steam 140 °C , 361.379 kPa
Kapasitas	:	11305.38 kg/jam = 24,923.838 lb/jam
Rate steam	:	237.3149 kg/jam = 523.1844 lb/jam

Dimensi	*Tube side* , steam			*Shell side* , Carbon Disulfide		
	do	=	3/4 in 16 BWG	IDs	=	17 1/4 in = 1.44
	di	=	0.62 in	B	=	4 in
	L	=	12 ft	de	=	0.72 in
	Nt	=	178	C'	=	0.25 in
	Pt	=	1 in	ΔPs	=	13.2 psi
	Tringular Pitch					
	ΔPt	=	4.04 psi			

5. Reaktor (R-110)

Fungsi : Tempat terjadinya reaksi antara Cl_2 dan CS_2

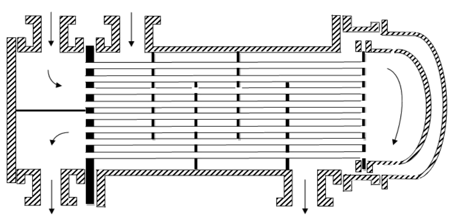
Tipe : Fixed-Bed Multitubular Reactor

Reaktor (R-110) dirancang oleh Frisca Fitrianingrum (1914017), lihat Bab VI Perancangan alat utama.

6. Kondensor (E-121)

Fungsi : Untuk menkondensasi produk reaktor (R-110)

Tipe : Horizontal Shell and Tube Heat Exchanger



Direncanakan :

- faktor kekotoran gabungan minumum (Rd)	=	0.004	jam.ft^2.°F/Btu
- Δp maksimum aliran shell	=	10	psi
- Δp maksimum aliran tube	=	2.5	psi

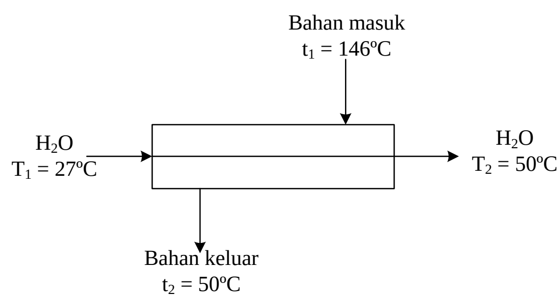
Dasar perencangan :

Dari Appendix B didapatkan data sebagai berikut:

- Massa bahan masuk	=	15,339.223	kg/jam
	=	33,816.850	Ib/jam
- Suhu bahan masuk (t_1)	=	146 °C =	295.06 °F
- Suhu bahan keluar (t_2)	=	50 °C =	122 °F
- Kebutuhan pendingin (m)	=	1,087.3708	kg/jam
	=	2,397.2176	Ib/jam

- Panas yang dibawa coolant = 201,796.4407 kkal/jam
  = 800,271.4177 btu/jam
- H_2O masuk pada suhu (T_1) = 27 °C = 81 °F = 300.15 K
- H_2O keluar pada suhu (T_2) = 50 °C = 122 °F = 323.15 K
- Digunakan pipa ukuran 1 in OD, BWG 16, L = 20 ft, P_T = 1,25 in
- Shell side : Produk R-110
- Tube side : Cooling water
- Susunan tube segitiga (triangular pitch)

Perhitungan :



A. Menghitung ΔT_{LMTD}

Δt_1 = $T_1 - t_2$ = 300 °F - 122 °F = 178 °F

Δt_2 = $T_2 - t_1$ = 323 °F - 295.06 °F = 28 °F

$$\Delta T_{LMTD} = \frac{\Delta t_1 - \Delta t_2}{\ln \Delta t_1/\Delta t_2}$$ (Kern, Pers.5.14 Hal.89

$$= \frac{178 - 28.09}{\ln (178 / 28.09)}$$

= 81.24 °F

dipilih tipe HE 2-4

B. Menghitung suhu kalorik

Tc = $(T_1 + T_2) / 2$ = 101 °F = 39 °C = 311.65 K

tc = $(t_1 + t_2) / 2$ = 209 °F = 98.1 °C = 371.2216 K

C. Trial U_D

Dari Kern hal 840 tabel 8 diperoleh:

Range U_D = 2-50 Btu/jam ft^2. °F

Dicoba U_D = 20 Btu/jam ft^2. °F

Dari App.B didapatkan Q = 272588.72 kkal/jam
= 1081718.4 Btu/jam

$$A = \frac{Q}{U_D \cdot \Delta t} = \frac{1081718.4475}{20 \times 81.2382} = 3328.8488 \quad ft^2$$

dengan,

do_{tube} = 1 in

BWG = 16

Dari Kern, tabel 10, hal. 843, diperoleh harga a" = 0.2618 ft^2/ft

$$Nt = \frac{A}{a'' \cdot L} = \frac{3328.8488}{0.2618 \times 20} = 636 \quad \text{buah}$$

Dari Kern, tabel 9, hal. 842, diperoleh :

IDs = 35 in

n = 4

Nt = 562

$$U_D \text{ koreksi} = \frac{Nt}{Nt \text{ standar}} \times U_D \text{ trial}$$

$$= \frac{636}{562} \times 20 = 22.62 \quad \text{Btu/jam ft}^2 \cdot {}^oF$$

Dari Kern, tabel 28, hal. 838, diperoleh :

de = 0.72 in

Viskositas aliran pada shell (bahan):

Dari Perry 8th Edition tabel 2-312 Hal. 2-421didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
CS2	5.82E-08	0.9262	44.581		
H_2O	1.71E-08	1.1146			
Cl2	2.60E-07	0.7423	98.3		
CO2	2.15E-06	0.46	290		
CCl4	3.137.E-06	0.3742	491.5		

dimana μ dalam Pa.s $\mu = \dfrac{C_1 T^{C2}}{1 + C_3/T + C_4/T^2}$

Dari J.A.Dean didapatkan μ S2Cl2 = 1.90800 cP = 0.0019 Pa.s

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
CS2	399.35055	0.0260346	0.00004	2.8641E-05	7.457E-07
H_2O	40.33844	0.0026298	2.E-06	1.082E-06	2.846E-09
Cl2	1119.2325	0.0729654	0.00083	0.00055552	4.053E-05

CO2	113.05379	0.0073702	0.02109	0.01417107	0.0001044
CCl4	6384.3543	0.4162111	0.03435	0.02308151	0.0096068
S2Cl2	7282.893	0.4747889	0.00191	0.00128212	0.0006087
Total	15339.223	1.0000	0.05822	0.0391	0.010361

$$\mu \text{ campuran} = \frac{\sum xi.\mu i}{\sum xi}$$

$$= \frac{0.010361}{1.0000} = 0.010361 \text{ lb/ft.s} = 37.30048 \text{ lb/ft.jam}$$

Viskositas aliran pada tube (cooling water):

Dari Perry 8th Edition tabel 2-313Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
H_2O	-52.84300	3703.6000	5.8660	-5.9.E-29	10

dimana μ dalam Pa.s

$$\mu = \exp(C1 + C2/T + C3\ln T + C4T^{C5}$$

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
H_2O	27.0000	1.0000	0.00069	0.000464	0.000464

Densitas aliran pada shell (bahan):

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
CS2	76	1.79680	0.28749	552.000	0.32260
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06
Cl2	71	2.32000	0.27645	417.150	0.29260
CO2	44	2.76800	0.26212	304.2100	0.29080
CCl4	154	0.99835	0.27400	556.3500	0.28700

dimana, ρ dalam mol/m^3

Dari J.A.Dean didapatkan ρ S2Cl2 = 0.68880 g/cm^3 = 688.80 kg/m^3

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
CS2	399.35055	0.0260	232.8941	6.0552
H_2O	40.33844	0.0026	53.8243	0.1399
Cl2	1119.2325	0.0730	250.1024	18.2575
CO2	113.05379	0.0074	164.9945	1.2210
CCl4	6384.3543	0.4162	252.2693	104.9945
S2Cl2	7282.893	0.4748	688.8000	327.0422
Total	15339.223	1.0000	1642.8845	457.7103

ρ campuran = ∑xi.ρi

ρ campuran = $\sum xi$

$= \frac{457.7103}{1.0000} = 457.7103$ kg/m^3 = 28.56113 lb/ft^3

Densitas aliran pada tube (cooling water):

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06

dimana, ρ dalam mol/m^3 $\rho = C_1 + C_2T + C_3T^2 + C_4T^3$

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	ρ (lb/ft^3)	xi.ρi
H_2O	1087.3708	1.0000	996.0587	65.9817	65.9817
Total	1087.3708	1.0000	996.0587	65.9817	65.9817

Kesimpulan sementara hasil perancangan :

Type HE : 2-4

Bagian *Tube*

do = 1 in, 16 BWG

L = 16 ft Nt = 562

Susunan segitiga, n = 4

di = 0.8700 in = 0.073 ft

a' = 0.5940 in^2 = 0.050 ft^2

a" = 0.2618 ft^2/ft

Pt = 1.25 in

Bagian *Shell*

IDs = 35 in = 2.92 ft

n' = 2

B = 8 in = 0.67 ft

de = 0.72 in = 0.06 ft

C' = 1 1/4 - 1 = 0.25

Evaluasi Perpindahan Panas

Cold fluid: tube, cooling water	Hot fluid: shell, produk R-110
1. Menghitung NRe	1'. Menghitung NRe
$a_t = \frac{Nt \times a'}{n \times 144}$	$a_s = \frac{IDs \times C' \times B}{n' \times Pt \times 144}$
$= \frac{562 \times 0.050}{4 \times 144}$	$= \frac{2.917 \times 0.25 \times 8}{2 \times 1.3 \times 144}$
= 0.0483 ft^2	= 0.0162 ft^2
$G_t = \frac{m}{a_t}$	$G_s = \frac{M}{a_s}$
$= \frac{2397.2176 \text{ lb/jam}}{0.0483 \text{ ft}^2}$	$= \frac{33816.850 \text{ lb/jam}}{0.0162 \text{ ft}^2}$
= 49635.05 lb/jam.ft^2	= 2086982.7419 lb/jam.ft^2
pada Tc = 101 ^{o}F	pada tc = 209 ^{o}F

μ = 0.000464 lb/ft.s
= 1.670887 lb/ft.jam
di = 0.87 in
= 0.073 ft

$N_{re\,p} = \frac{G_t \times di}{\mu}$

$= \frac{49635.05 \times 0.073}{1.670887}$

= 2153.67

Velocity

$v = \frac{G_t}{3600\rho}$

$= \frac{49635.05}{3600 \times 65.982}$

= 2.0895961 fps

μ = 0.010361 lb/ft.s
= 37.30048 lb/ft.jam
de = 0.72 in
= 0.06 ft

$Nre_s = \frac{G_s \times de}{\mu}$

$= \frac{2086982.7419 \times 0.06}{37.30048}$

= 3357.0340

2. Menghitung harga koefisien film perpindahan panas

Dari Kern, Fig. 25 Hal.835 , didapatkan:

hi = 492 Btu/jam.ft^{2o}F
faktor koreksi = 0.94

sehingga,

$hic = hi\left(\frac{di}{do}\right)$

$= 462.48\left(\frac{0.8700}{1.00}\right)$

= 402.36 Btu/jam.ft^{2o}F

2'. Menghitung harga koefisien film
Untuk condensor horizontal,
ho berkisar 150-300 Btu/jam.ft^2 ^{o}F

Trial ho = 300 Btu/jam.ft^{2o}F

$tw = tc + \frac{ho}{ho + hio}\left(tc\text{-}Tc\right)$

$= 209 + \frac{300}{300 + 402}\left(208.5 - 10\right.$

= 254.33 ^{o}F

$tf = \frac{Tc + tw}{2} = \frac{208.5 + 254.3}{2}$

= 231 ^{o}F

sehingga,

Dari Kern, Tabel 4 hal.800 didapatkan:

kf = 0.11002 Btu/jam.ft^2.^{o}F/ft

Dari Kern, Tabel 6 hal.808 didapatkan:

sf = 1.537 Btu/jam.ft^2.^{o}F/ft

Dari Kern, Fig.14hal.823 didapatkan:

μf = 0.25571 cp

$G'' = \frac{M}{L\ Nt^{2/3}}$

$= \frac{33{,}816.850}{16 \times 562^{2/3}}$

= 31.0353 lb/jam.ft

Dari Kern, Fig.12.9 hal.267 didapatkan:

ho = 325

$$\varepsilon = \frac{325 - 300}{300}$$

= 8% < 10% *ho memenuhi*

Clean overall coefficient Uc :

$$U_c = \frac{hio \cdot ho}{hio + ho} = \frac{402.4 \times 325}{402.4 + 325} = 650.00 \ \text{Btu/ft}^2\text{.jam}^0\text{F}$$

Dirt factor (faktor kekotoran) pipa terpakai

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

$$= \frac{650 - 22.6}{650 \times 22.6} = 0.04266 \ \text{jam.ft}^2.°\text{F/Btu}$$

Karena harga Rd hitung > Rd tetapan, maka rancangan HE memenuhi.

Evaluasi ΔP

Cold fluid: tube, cooling water	Hot fluid: shell, produk R-110
1. Pada NRe_t = 2153.6713	1'. Pada Nres = 3357.0340
Dari Kern,fig. 26 hal.836, diperoleh: f = 0.00013	Dari Kern,fig. 29 hal.839, diperoleh: f = 0.0023
sg = 1	2'. No. of crosess
2. ΔP karena panjang pipa :	$(N+1) = \frac{12L}{B} = \frac{12 \times 16}{8}$
$\Delta Pl = \frac{1}{2} \cdot \frac{f.Gt^2.L.n}{5{,}22 \times 10^{10}.di.sg.\phi}$	= 24
$= \frac{0.00013 \times 49635.0^2 \times 16 \times 4}{2 \times 5{,}22.10^{10} \times 0.073 \times 1 \times 1}$	bahan = 28.56113 lb/ft^3
= 0.0027 psi	$sg = \frac{\rho}{62.5}$
ΔP karena tube passes	$= \frac{28.56113}{62.5}$
Dari Kern,fig. 27 hal.837,diperoleh:	= 0.456978
$\left[\frac{v^2}{2gc}\right]\frac{\rho}{144}$ = 0.55 , sehingga	4'. $\Delta Ps = \frac{f.Gs^2.IDs.(N+1)}{5{,}22 \times 10^{10}.de.sg.\phi}$
$\Delta Pn = \frac{4n}{sg}\left[\frac{v^2}{2gc}\right]\frac{\rho}{144}$	$= \frac{0.0023 \times 2086982.7^2 \times 2.92 \times 24}{5{,}22 \times 10^{10} \times 0.06 \times 0.457 \times 0.97}$
$= \frac{4 \times 4}{1} \times 0.55$	= 5.05097 psi < 10.0 psi
= 0.88 psi	*desain memenuhi*
sehingga,	
ΔPt total = 0.0027 + 0.88	
= 0.88 psi < 2.5 psi	
desain memenuhi	

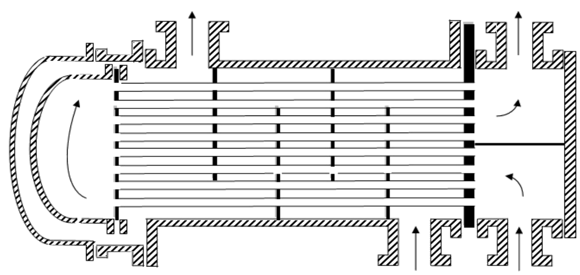
Spesifikasi Heater

Fungsi	:	Untuk menkondensasi produk reaktor (R-110)
Kode alat	:	E-121
Tipe	:	Horizontal Shell and Tube Heat Exchanger
Bahan Konstruksi	:	Carbon steel SA-135 Grade B
Media pendingin	:	Cooling water 27 ^oC ,
Kapasitas	:	15,339.223 kg/jam = 33,816.850 lb/jam
Rate pendingin	:	1087.3708 kg/jam = 2,397.2176 lb/jam
Dimensi		*Tube side* , cooling water / *Shell side* , produk R-110
		do = 1 in 16 BWG / IDs = 35 in = 2.92
		di = 0.87 in / B = 8 in
		L = 16 ft / de = 0.72 in
		Nt = 562 / C' = 0.25 in
		Pt = 1.25 in / ΔPs = 5.05 psi
		Tringular Pitch
		ΔPt = 0.88 psi

7. Reboiler (E-133)

Fungsi : Menguapkan bottom product D-130

Tipe : Kettle Reboiler, Shell and Tube Heat Exchanger



Direncanakan :

- faktor kekotoran gabungan minumum (Rd) = 0.004 jam.ft^2.^{o}F/Btu
- Δp maksimum aliran shell = 10 psi
- Δp maksimum aliran tube = 2.5 psi

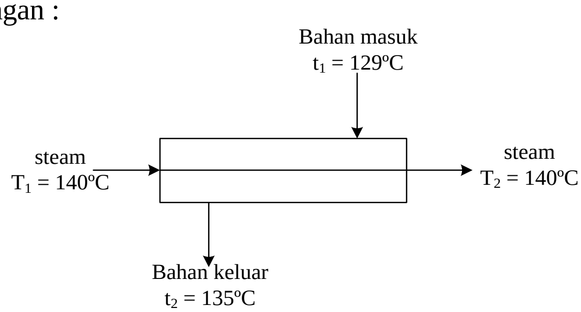
Dasar perencangan :

Dari Appendix B didapatkan data sebagai berikut:

- Massa bahan masuk = 24,846.683 kg/jam
  = 54,776.998 Ib/jam
- Suhu bahan masuk (t_1) = 129 ^oC = 264.20 ^oF
- Suhu bahan keluar (t_2) = 135 ^oC = 275 ^oF
- Kebutuhan steam (m) = 142.1786 kg/jam
  = 313.4469 Ib/jam
- Panas yang dibawa steam = 72,856.3097 kkal/jam
  = 288,928.8931 btu/jam

- steam masuk pada suhu (T_1) = 140 ^oC = 284 ^oF = 413.15 K
- steam keluar pada suhu (T_2) = 140 ^oC = 284 ^oF = 413.15 K
- Digunakan pipa ukuran 1 in OD, BWG 16, L = 16 ft, P_T = 1,25 in
- Shell side : Bottom product D-130
- Tube side : Steam
- Susunan tube segitiga (triangular pitch)

Perhitungan :



A. Menghitung ΔT_{LMTD}

$\Delta t_1 = T_1 - t_2$ = 284 ^oF - 275 ^oF = 9 ^oF

$\Delta t_2 = T_2 - t_1$ = 284 ^oF - 264.20 ^oF = 20 ^oF

$$\Delta T_{LMTD} = \frac{\Delta t_1 - \Delta t_2}{\ln \Delta t_1/\Delta t_2}$$ (Kern, Pers.5.14 Hal.89

$$= \frac{9 - 19.80}{\ln(9 / 19.80)}$$

$$= 13.70\ ^oF$$

dipilih tipe HE 2-4

B. Menghitung suhu kalorik

Tc = $(T_1 + T_2)/2$ = 284 ^oF = 140 ^oC = 413.15 K

tc = $(t_1 + t_2)/2$ = 270 ^oF = 132 ^oC = 405.15 K

C. Trial U_D

Dari Kern hal 840 tabel 8 diperoleh:

Range U_D = 100-500 Btu/jam $ft^2.\ ^oF$

Dicoba U_D = 100 Btu/jam $ft^2.\ ^oF$

Dari App.B didapatkan Q = 72856.31 kkal/jam

= 289116.93 Btu/jam

$$A = \frac{Q}{U_D \cdot \Delta t} = \frac{289116.9291}{100 \times 13.6976} = 211.0707\ ft^2$$

dengan,

do_{tube} = 1 in

BWG = 16

Dari Kern, tabel 10, hal. 843, diperoleh harga a" = 0.2618 ft^2/ft

$$Nt = \frac{A}{a'' \cdot L} = \frac{211.0707}{0.2618 \times 16} = 50 \text{ buah}$$

Dari Kern, tabel 9, hal. 842, diperoleh :

IDs = 12 in

n = 4

Nt = 48

$$U_D \text{ koreksi} = \frac{Nt}{Nt \text{ standar}} \times U_D \text{ trial}$$

$$= \frac{50}{48} \times 100 = 104.98 \text{ Btu/jam ft}^2. ^oF$$

Dari Kern, tabel 28, hal. 838, diperoleh :

de = 0.72 in

Viskositas aliran pada shell (bahan):

Dari Perry 8th Edition tabel 2-312 Hal. 2-421didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
H_2O	1.71E-08	1.1146			
CCl4	3.137.E-06	0.3742	491.5		

dimana μ dalam Pa.s $\mu = \dfrac{C_1 T^{C2}}{1 + C_3/T + C_4/T^2}$

Dari J.A.Dean didapatkan μ S2Cl2 = 1.90800 cP = 0.0019 Pa.s

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
H_2O	155.01835	0.006239	0.00020	0.00013439	8.385E-07
CCl4	24417.782	0.0110229	0.04	0.02687876	0.0002963
S2Cl2	24846.683	0.9827381	0.00191	0.00128212	0.00126
Total	49419.483	1.0000	0.04211	0.0283	0.001557

$$\mu \text{ campuran} = \frac{\sum xi.\mu i}{\sum xi}$$

$$= \frac{0.001557}{1.0000} = 0.001557 \text{ lb/ft.s} = 5.605579 \text{ lb/ft.jam}$$

Viskositas aliran pada tube (steam):

Dari Perry 8th Edition tabel 2-312 Hal. 2-421didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
H_2O	1.710.E-08	1.1146			

dimana μ dalam Pa.s

$$\mu = \exp(C1 + C2/T + C3 \ln T + C4T^{C5}$$

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
H_2O (steam)	142.1786	1.0000	2.E-06	0.000001	0.000001

Densitas aliran pada shell (bahan):

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06
CCl4	154	0.99835	0.27400	556.3500	0.28700

dimana, ρ dalam mol/m^3

Dari J.A.Dean didapatkan ρ S2Cl2 = 0.68880 g/cm^3 = 688.80 kg/m^3

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
H_2O	155.01835	0.0062	53.1895	0.3298
CCl4	273.88325	0.0110	246.6174	2.7128
S2Cl2	24417.782	0.9872	688.8000	679.9834
Total	24846.683	1.0	988.6068	683.0259

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

$$= \frac{683.0259}{1.0044} = 680.0338 \text{ kg/m}^3 = 42.43411 \text{ lb/ft}^3$$

Type HE : 2-4

Bagian *Tube*

do = 1 in, 16 BWG

L = 16 ft Nt = 48

Susunan segitiga, n = 4

di = 0.8700 in = 0.073 ft

a' = 0.5940 in^2 = 0.050 ft^2

a" = 0.2618 ft^2/ft

Pt = 1.25 in

Bagian *Shell*

IDs = 12 in = 1 ft

n' = 2

B = 8 in = 0.67 ft

de = 0.72 in = 0.06 ft

C' = 1 1/4 - 1 = 0.25

Evaluasi Perpindahan Panas

Hot fluid: tube, steam	Cold fluid: shell, bottom product D-130
1. Menghitung NRe	1'. Menghitung NRe
$a_t = \frac{Nt \times a'}{n \times 144}$	$a_s = \frac{IDs \times C' \times B}{n' \times Pt \times 144}$
$= \frac{48 \times 0.050}{4 \times 144}$	$= \frac{1 \times 0.25 \times 8}{2 \times 1.3 \times 144}$

$= 0.0041 \ ft^2$

$G_t = \frac{m}{a_t}$

$= \frac{313.447 \text{ lb/jam}}{0.0041 \ ft^2}$

$= 75987.12 \text{ lb/jam.ft}^2$

pada Tc = 284 ^oF

μ = 0.000001 lb/ft.s

= 0.004389 lb/ft.jam

di = 0.87 in

= 0.073 ft

$N_{re\,p} = \frac{G_t \times di}{\mu}$

$= \frac{75987.12 \times 0.073}{0.004389}$

= 1255244.54

2. J_H = - (*steam*)

3. Menghitung harga koefisien fil

perpindahan panas

untuk steam didapatkan:

h_{io} = 1500 Btu/ft^2.jam^{0}F

$= 0.00556 \ ft^2$

$G_s = \frac{M}{a_s}$

$= \frac{54776.998 \text{ lb/jam}}{0.0056 \ ft^2}$

$= 9859859.6650 \text{ lb/jam.ft}^2$

pada tc = 270 ^oF

μ = 0.001557 lb/ft.s

= 5.60558 lb/ft.jam

de = 0.72 in

= 0.06 ft

$Nre_s = \frac{G_s \times de}{\mu}$

$= \frac{9859859.6650 \times 0.06}{5.60558}$

= 105536.2049

2'. -

3'. Menghitung harga koefisien film

trial ho maksimal 300 Btu/jam.ft^2 ^oF

Trial ho = 115 Btu/jam.ft^{2o}F

$tw = tc + \frac{ho}{ho + hio}\left(tc - Tc\right)$

$= 270 + \frac{115}{115 + 1500}\left(269.6 - 28\right.$

= 268.575 ^oF

Δt = tc+ tw = 269.6 - 268.6

= 1.03 ^oF

Dari Kern, fig.15.11hal.474 didapatkan:

hs = 35 Btu/ft^2.jam^{0}F

hv = 200 Btu/ft^2.jam^{0}F

Dari App. B didapatkan:

Q1 = 352276.9081 kkal/jam

= 1397037.231 btu/jam

Q2 = 72856.30967 kkal/jam

= 288928.8931 btu/jam

$$ho = \frac{Q}{\frac{Q1}{hs} + \frac{Q2}{hv}}$$

$$= \frac{425133.2178}{\frac{1397037.23}{35} + \frac{288,928.89}{200}}$$

$$= 102.7885$$

$$\varepsilon = \frac{115.0000 - 102.7885}{115.0000}$$

$= 10.619\%$ *memenuhi*

Clean overall coefficient Uc :

$$U_c = \frac{hio \cdot ho}{hio + ho} = \frac{1500 \times 103}{1500 + 103} = 205.58 \text{ Btu/ft}^2\text{.jam}^0\text{F}$$

Dirt factor (faktor kekotoran) pipa terpakai

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

$$= \frac{205.58 - 104.98}{205.58 \times 104.98} = 0.00466 \text{ jam.ft}^2\text{.°F/Btu}$$

Karena harga Rd hitung > Rd tetapan, maka rancangan HE memenuhi.

Evaluasi ΔP

Hot fluid: tube, steam	Cold fluid: shell, bottom produk D-130
1. Pada NRe_t = 1255244.5383	1'. Untuk Kettle Reboiler Δp s diabaikan
Dari Kern,fig. 26 hal.836,	
diperoleh: f = 0.00005	
sg = 1	
2. ΔP karena panjang pipa :	
$\Delta Pl = \frac{1}{2} \cdot \frac{f.Gt^2.L.n}{5,22 \times 10^{10}.di.sg.\phi}$	
$= \frac{0.00005 \times 75987.1^2 \times 16 \times 4}{2 \times 5,22.10^{10} \times 0.073 \times 1 \times 1}$	
= 0.0024 psi	
ΔP karena tube passes	
Dari Kern,fig. 27 hal.837,diperoleh:	
$\left[\frac{v^2}{2gc}\right]\frac{\rho}{144}$ = 0.006 , sehingga	

$\Delta Pn = \frac{4n}{sg}\left[\frac{v^2}{2gc}\right]\frac{\rho}{144}$

$= \frac{4 \times 4}{1} \times 0.006$

$= 0.0096$ psi

sehingga,

ΔPt total $= 0.0024 + 0.0096$

$= 0.01$ psi < 2.5 psi

desain memenuhi

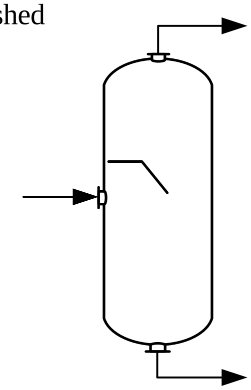
Spesifikasi Reboiler

Fungsi	:	Menguapkan bottom product D-130
Kode alat	:	E-133
Tipe	:	Kettle Reboiler, Shell and Tube Heat Exchanger
Bahan Konstruksi	:	Carbon steel SA-135 Grade B
Media pemanas	:	Saturated steam 0 ^oC , 0.000 kPa
Kapasitas	:	24,846.683 kg/jam = 54,776.998 lb/jam
Rate steam	:	142.1786 kg/jam = 313.4469 lb/jam
Dimensi		*Tube side* , steam / *Shell side* ,bottom produk D-1
		do = 1 in 16 BWG / IDs = 12 in = 1.00
		di = 0.87 in / B = 8 in
		L = 16 ft / de = 0.72 in
		Nt = 48 / C' = 0.25 in
		Pt = 1.25 in
		Tringular Pitch
		ΔPt = 0.012 psi

7. Flash Drum (D-120)

Fungsi : Memisahkan liquid dan gas yang keluar dari kondensor (E-122)

Tipe : Silinder vertikal dengan tutup atas dan bawah berbentuk standard dished



Direncanakan :

Bahan konstruksi = Carbon steels SA-135 Grade B

Allowable stress (f) = 12750 psi

Tipe pengelasan = Double welded butt joint (E = 0.8)

Faktor korosi (C) = 1/16 in
Waktu tinggal = 1 jam
Volume ruang kosong = 30% Volume total
Kondisi operasi :
Suhu operasi = 50 ^oC = 323.15 K
Tekanan operasi = 1 atm = 14.7 psia

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
CS2	76	1.79680	0.28749	552.000	0.32260
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06
Cl2	71	2.32000	0.27645	417.150	0.29260
CO2	44	2.76800	0.26212	304.2100	0.29080
CCl4	154	0.99835	0.27400	556.3500	0.28700

dimana, ρ dalam mol/m^3

$$\rho = \frac{C_1}{C_2^{\left(1 + \left(1 - \frac{T}{C_3}\right)^{C_4}\right)}}$$

untuk water mengunakan persamaan:

$$\rho = C_1 + C_2 T + C_3 T^2 + C_4 T^3$$

Dari J.A.Dean didapatkan ρ S2Cl2 = 0.68880 g/cm^3 = 688.80 kg/m^3

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
CS2	399.35055	0.0260	241.1948	6.2711
H_2O	40.33844	0.0026	991.5792	2.5781
Cl2	1119.2325	0.0730	261.1835	19.0664
CO2	113.05379	0.0074	175.4651	1.2984
CCl4	6384.3543	0.4162	260.4997	108.4200
S2Cl2	7282.893	0.4748	688.8000	327.0422
Total	15339.223	1.0000	2618.7224	464.6762

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

$$= \frac{464.6762}{1.0000} = 464.6762 \text{ kg/m}^3 = 28.99580 \text{ lb/ft}^3$$

Rate bahan masuk (m) = 15339.223 kg/jam
= 33816.850 lb/jam

PERHITUNGAN

A. Menghitung Volume Tangki

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

$$= \frac{15339.223 \text{ kg/jam}}{464.6762 \text{ kg/m}^3} \times 1 \text{ jam}$$

$$= 33.0106 \text{ m}^3$$

$$\text{Volume tangki} = \frac{33.0106}{0.7} = 47.1579 \text{ m}^3$$

B. Menentukan Dimensi tangki

Asumsi Ls = 3 di

Volume tanki = Volume silinder + 2 Volume tutup

$$47.1579 = \frac{\pi}{4} di^2 Ls + 2(0{,}0847\ di^3)$$

$$47.1579 = \frac{\pi}{4} di^2 \times 3\ di + 2(0{,}0847\ di^3)$$

$$47.1579 = 2.5298\ di^3$$

$$di^3 = 18.6410$$

$$di = 2.6515 \text{ m} = 104.39 \text{ in} = 8.6990 \text{ ft}$$

C. Menghitung Tinggi Liquida

$$\text{Tinggi liquida (HL)} = \frac{\text{Volume liquida}}{\frac{1}{4}\pi \times di^2}$$

$$= \frac{33.0106}{\frac{1}{4} \times 3.14 \times 2.6515^2}$$

$$= 5.9814 \text{ m} = 235.4890 \text{ in} = 19.6238 \text{ ft}$$

D. Menentukan Tekanan Design (Pi)

$$\text{Tekanan hidrostatik (Ph)} = \frac{\rho\ (HL-1)}{144}$$

$$= \frac{28.9958 \times (19.6238 - 1)}{144}$$

$$= 3.7501 \text{ psia}$$

$$= 18.4501 \text{ psig}$$

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

= 14.7 + 3.7501
= 18.4501 psia
= 1.2721 bar

E. Menghitung Tebal Silinder (ts)

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

$= \frac{18.4501 \times 104.3893}{2\ (\ 12750 \times 0.8 - 0.6 \times 18.4501\ )} + \frac{1}{1}$

$= 0.157 \times \frac{16}{16}$

ts $= \frac{2.5114}{16}$ in $\approx \frac{4}{16}$ in = 0.25 in

do = di + 2(ts)
= 104.3893 + 2(0.25)
= 104.8893 in ≈ 96 in

Berdasarkan "Brownel and Young" tabel 5.7 hal 90, didapatkan :

icr = 5 7/8 in
r = 96 in

di_{baru} = do_{st} - 2ts
= 96 - 2(0.25)
= 95.500 in
= 7.9583 ft

F. Menghitung Tinggi Silinder (Ls)

Tinggi silinder (Ls) = 3 × di
= 3 × 7.9583 ft
= 23.8750 ft
= 286.5 in

G. Menghitung Dimensi Tutup Atas Dan Tutup Bawah

Bentuk tutup atas dan bawah adalah standar dished, sehingga :

r = di_{baru}

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

$= \frac{0.885 \times 18.4501 \times 95.500}{2\ (\ 12750 \times 0.8 - 0.1 \times 18.4501\ )} + \frac{1}{1}$

$= 0.1390 \times \frac{16}{16}$

$= \frac{2.2232}{16} \approx$ 4/16 in

Tinggi Tutup = 0.169 × di

= 0.169 × 95.5000 in
= 16.1395 in

H. Menghitung Tinggi Tangki (H)

Tinggi tangki (H) = Tinggi silinder + Tinggi tutup atas dan bawah
= 286.5 + 2 x 16.1395
= 318.7790 in
= 26.5649 ft

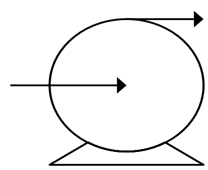
Spesifikasi Flash Drum

Fungsi	:	Memisahkan liquid dan gas yang keluar dari kondensor
Kode alat	:	D-130
Tipe	:	Silinder vertikal dengan tutup atas dan bawah berbentuk standard dished
Kapasitas	:	47.1579 m^3
Suhu operasi	:	323.15 K
Tekanan operasi	:	1 atm
Dimensi		
Diameter shell	:	8.000 ft
Tinggi shell	:	23.8750 ft
Tebal shell	:	4/16 in
Tinggi tutup	:	1.3450 ft
Tebal tutup	:	4/16 in
Tipe pengelasan	:	Double welded but joint (E = 0.8)
Bahan Konstruksi	:	Carbon steels SA-135 Grade B

8. Pompa sentrifugal (L-134A)

Fungsi : Untuk mengalirkan liquida dari flash drum (D-120) menuju heater (E-131)

Tipe : Centrifugal pump



Direncanakan :

Bahan konstruksi = Carbon steel

Jumlah = 1 buah

Kondisi operasi :

Suhu (T) = 50 ^oC = 323.15 K

Tekanan (P) = 1 atm = 14.7 psia

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4

CS2	76	1.79680	0.28749	552.000	0.32260
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06
CCl4	154	0.99835	0.27400	556.3500	0.28700

dimana, ρ dalam mol/m^3

$$\rho = \frac{C_1}{C_2^{\left(1 + \left(1 - \frac{T}{C_3}\right)^{C_4}\right)}}$$

untuk water mengunakan persamaan:

$$\rho = C_1 + C_2 T + C_3 T^2 + C_4 T^3$$

Dari J.A.Dean didapatkan ρ S2Cl2 = 0.68880 g/cm^3 = 688.80 kg/m^3

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
CS2	353.7412	0.0261	241.1948	6.2937
H_2O	39.785453	0.0029	991.5792	2.9101
CCl4	6958.9205	0.5133	260.4997	133.7206
S2Cl2	6204.1545	0.4576	688.8000	315.2281
Total	13556.602	1.0000	2182.0737	458.1524

ρ campuran = $\frac{458.1524}{1.0000}$ = 458.1524 kg/m^3 = 28.58871 lb/ft^3

Dari Perry 8th Edition tabel 2-313 Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
CS2	-10.3060	703.01			
H_2O	-52.8430	3703.6	5.866	-5.88E-29	10
CCl4	-8.0738	1121.1	-0.4726		

dimana μ dalam Pa.s $\mu = \exp(C1 + C2/T + C3\ln T + C4T^{C5}$

Dari J.A.Dean didapatkan μ S2Cl2 = 1.90800 cP = 0.0019 Pa.s

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
CS2	353.7412	0.0260936	0.00029	0.00019784	5.162E-06
H_2O	39.785453	0.0029348	0.00056	0.000376	1.103E-06
CCl4	6958.9205	0.5133234	0.00065	0.00043822	0.0002249
S2Cl2	6204.1545	0.4576482	0.00191	0.00128212	0.0005868
Total	13556.602	1.0000	0.00341	0.0023	0.000818

μ campuran = $\frac{\sum xi.\mu i}{\sum xi}$

$= \dfrac{0.000818}{1.0000} = 0.000818$ lb/ft.s = 2.944699 lb/ft.jam

Rate bahan masuk (m) = 13556.602 kg/jam
= 29886.884 lb/jam

PERHITUNGAN :

A. Menghitung Rate Volumetrik (Q)

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

$= \dfrac{29886.884}{28.5887}$

= 1045.4087 ft^3/jam

= 0.2904 ft^3/s

= 130.3378 gpm

$Di_{optimum} = 3{,}9\ Q^{0,45} \times \rho^{0,13}$ (Pers.15 "Petters&Timmerhaus",hal 496)

$= 3.9 \times 0.2904^{0,45} \times 28.5887^{0,13}$

= 3.4571 ≈ 3 in

= 0.2500 ft

Untuk pipa ukuran 3 in sch 40

Dari Brownell and Young, App.K-2 Hal.387 didapatkan:

OD = 3.500 in = 0.2917 ft

ID = 3.068 in = 0.2557 ft

A = 0.05132 ft^2

B. Menentukan Kecepatan Aliran Fluida (v)

Kecepatan aliran fluic $= \dfrac{Q}{A}$

$= \dfrac{1045.4087}{0.05132}$

= 20370.6288 ft/jam

= 5.6585 ft/s

C. Menentukan Bilangan Reynold

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

$= \dfrac{0.25567 \times 5.6585 \times 28.5887}{0.000818}$

= 50562.931 ≥ 4000 (aliran turbulen)

DariGeankoplis, Fig. 2.10-3 Hal. 88 didapatkan:

Equivalent rougness(ε) = 4.6E-05 m

Relative rougness $\frac{\varepsilon}{D}$ = 0.0006

Faktor friksi (f) = 0.0006

α = 1

D. Menentukan Panjang Pipa

Asumsi :

- Panjang pipa lurus = 150 ft
- elbow 90^o = 3 buah

  Le/D = 35 (Geankoplis,Tabel 2-10.1 Hal 93)

  L elbow = 35 ID

  = 35 × 3 × 0.29167 ft

  = 30.625 ft
- Globe valve = 1 buah

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

  L elbow = 300 ID

  = 300 × 1 × 0.29167 ft

  = 87.500 ft

Panjang pipa total (L) = Pipa lurus + elbow 90^o + globe valve

= 150 + 30.625 + 87.500

= 268.125 ft

= 3218 in

E. Menentukan friksion Loss

1. Friksi pada pipa lurus

$$F_f = 4f \frac{\Delta L}{D} \times \frac{v^2}{2g_c}$$ (Geankoplis, Pers.2-10.6 Hal 86)

$$= 4 \times 0.0006 \frac{268.1250}{0.2556667} \times \frac{5.6585^2}{2 \times 32.2}$$

= 1.2524 lbf.ft/lbm

2. Kontraksi pada keluaran tangki

$$hc = Kc \frac{v^2}{2g_c}$$ (Geankoplis, Pers.2-10.16 Hal 93)

$$= 0.55 \frac{5.6585^2}{2 \times 32.174}$$

= 0.2737 lbf.ft/lbm

3. Elbow 90^o, 2 buah

K_f = 0.75 (Geankoplis, Tabel 2.10-1 Hal. 93

$$hf = 2Kf \frac{v^2}{2g_c}$$ (Geankoplis, Pers.2-10.17 Hal 94)

$$= 2 \times 0.75 \frac{5.6585^2}{}$$

2×32.174

$= 0.7464$ lbf.ft/lbm

Total friksi (∑F) = 1.2524 + 0.2737 + 0.74638

= 2.2725 lbf.ft/lbm

F. Menentukan Kesetimbangan Mekanik

Direncanakan:

ΔZ = 30 ft

ΔP = 0 lb/ft^2

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

v_2 = 5.659 ft/s

α = 1 (aliran turbulen)

Sehingga Mechanical energy balance :

$$\frac{V_2 - V_1}{2.\alpha.gc} + \Delta Z\frac{g}{gc} + \frac{\Delta P}{\rho} + \sum F = -Ws$$

$$\frac{5.6585 - 0}{2 \times 1 \times 32.17} + 30 \frac{32.17}{32.17} + 2.2725 = -Ws$$

-Ws = 32.3604 lbf.ft/lbm

Dengan: Capacity = 130.34 gal/menit

μ campuran = 3.4141 Centipoise

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

Efisiensi pompa (η) = 90%

Ws = - η Wp

32.3604 = - 90% Wp

Wp = 35.9560 ft.lbf/lbm

mass flow rate (m) = Q x ρ

= 1045.4087×28.5887

= 29886.884 lbm/jam

= 8.3019 lbm/s

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

$$WHp = 35.9560 \times 8.3019 \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

WHp = 0.5427 hp

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

$$= \frac{0.5427}{90\%}$$

= 0.6030 Hp

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

Efisiensi motor = 90%

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

= $\frac{0.6030}{90\%}$

= 0.6700 Hp ≈ 1 Hp

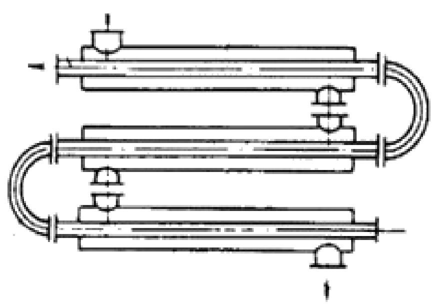
Spesifikasi Pompa Sentrifugal

Fungsi	:	Untuk mengalirkan liquida dari flash drum (D-120) menuju heater (E-131)
Kode alat	:	L-134a
Tipe	:	Centrifugal pump
Kapasitas	:	130.34 gpm
Suhu operasi	:	323.15 K
Tekanan operasi	:	1 atm
Efisiensi Pompa	:	90%
ΔP	:	0 lb/ft^2
Bahan Konstruksi	:	Carbon steel
Daya	:	1 Hp
Dimensi		
	NPS : 3 in	OD : 3.500 in A : 0.05132 ft^2
	Sch : 40	ID : 3.068 in

9. Heater (E-131)

Fungsi : Memanaskan liquida hingga bubble point-nya

Type : Double Pipe Heat Exchanger



Direncanakan :

faktor kekotoran gabungan minimum (Rd) = 0.001 jam.ft^2.^{0}F/Btu

Δp maksimum aliran = 10 psi

Δp maksimum steam = 2.5 psi

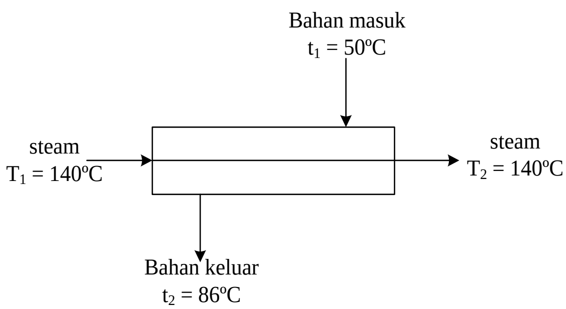
Dasar perencangan :

Dari Appendix B didapatkan data sebagai berikut:

- Massa bahan masuk = 13,556.602 kg/jam
  = 29,886.884 Ib/jam
- Suhu bahan masuk (t_1) = 50 ^{o}C = 122.00 ^{o}F
- Suhu bahan keluar (t_2) = 86 ^{o}C = 186.80 ^{o}F

- Kebutuhan steam (m) = 135.4097 kg/jam
  = 298.5242 Ib/jam
- Panas yang dibawa steam = 69,387.7542 kkal/jam
  = 275,173.5177 btu/jam
- steam masuk pada suhu (T_1) = 140 ^oC = 284 ^oF = 413.15 K
- steam keluar pada suhu (T_2) = 140 ^oC = 284 ^oF = 413.15 K

Perhitungan :



1. Menghitung Δt
   $\Delta t_1 = T_2 - t_1 = 284 - 122 = 162\ ^0F$
   $\Delta t_2 = T_1 - t_2 = 284 - 187 = 97.2\ ^0F$
   $$\Delta T_{LMTD} = \frac{\Delta t_1 - \Delta t_2}{\ln \frac{\Delta t1}{\Delta t2}} = \frac{162 - 97.2}{\ln \frac{162}{97.2}} = 126.853\ ^0F$$
2. Menghitung suhu caloric (Tc dan tc)
   Tc = $(T_1 + T_2) /$ = 284 ^oF = 140 ^0C = 413.15 K
   tc = $(t_1 + t_2) / 2$ = 154 ^oF = 68 ^0C = 341.15 K

   Viskositas aliran pada anulus (bahan):
   Dari Perry 8th Edition tabel 2-313 Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
CS2	-10.3060	703.01			
H_2O	-52.8430	3703.6	5.866	-5.88E-29	10
CCl4	-8.0738	1121.1	-0.4726		

dimana μ dalam Pa.s $\mu = \exp(C1 + C2/T + C3 \ln T + C4T^{C5}$

Dari J.A.Dean didapatkan μ S2Cl2 = 1.90800 cP = 0.0019 Pa.s

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
CS2	353.7412	0.0260936	0.00026	0.00017639	4.603E-06
H_2O	39.785453	0.0029348	0.00042	0.00028212	8.28E-07
CCl4	6958.9205	0.5133234	0.00053	0.00035569	0.0001826
S2Cl2	6204.1545	0.4576482	0.00191	0.00128212	0.0005868
Total	13556.602	1.0000	0.00312	0.0021	0.000775

$$\mu \text{ campuran} = \frac{\sum xi.\mu i}{\sum xi}$$

$$= \frac{0.000775}{1.0000} = 0.000775 \text{ lb/ft.s} = 2.789176 \text{ lb/ft.jam}$$

Viskositas aliran pada pipe (steam):
Dari Perry 8th Edition tabel 2-312 Hal. 2-421didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
H_2O	1.710.E-08	1.1146			

dimana μ dalam Pa.s

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
H_2O (steam)	135.4097	1.0000	2.E-06	0.000001	0.000001

Densitas aliran pada anulus (bahan):
Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
CS2	76	1.79680	0.28749	552.000	0.32260
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06
CCl4	154	0.99835	0.27400	556.3500	0.28700

dimana, ρ dalam mol/m^3

$$\rho = \frac{C_1}{C_2^{\left(1+\left(1-\frac{T}{C_3}\right)^{C_4}\right)}}$$

untuk water mengunakan persamaan:

$$\rho = C_1 + C_2 T + C_3 T^2 + C_4 T^3$$

Dari J.A.Dean didapatkan ρ S2Cl2 = 0.68880 g/cm^3 = 688.80 kg/m^3

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi

CS2	353.7412	0.0261	238.0526	6.2117
H_2O	39.785453	0.0029	983.2996	2.8858
CCl4	6958.9205	0.5133	257.3869	132.1227
S2Cl2	6204.1545	0.4576	688.8000	315.2281
Total	13556.602	1.0000	2167.5391	456.4482

ρ campuran $= \dfrac{456.4482}{1.0000} = 456.4482$ kg/m^3 $= 28.48237$ lb/ft^3

Trial ukuran DPHE
Dicoba ukuran DPHE : 4x 3" IPS sch.40 dengan aliran steam di bagian pipa.
Dari Kern, tabel 6.2 hal.110 didapatkan :

a_{an} = 3.14 in^2 = 0.0218 ft^2
a_p = 7.38 in^2 = 0.0513 ft^2
de = 1.14 in = 0.0950 ft
de' = 0.53 in = 0.0442 ft

Dari Kern, tabel 11 hal.844 didapatkan :

dop = 3.5 in = 0.0243 ft
dip = 3.07 in = 0.2557 ft
a" = 0.92 ft^2/ft

Evaluasi Perpindahan Panas

Hot fluid: pipe, Steam	Cold fluid: anulus, liquid product D-12
1. Menghitung NRe	1'. Menghitung NRe
$G_p = \dfrac{M}{a_p}$	$G_{an} = \dfrac{m}{a_{an}}$
$= \dfrac{298.5242 \text{ lb/jam}}{0.0513 \text{ ft}^2}$	$= \dfrac{29886.884 \text{ lb/jam}}{0.0218 \text{ ft}^2}$
= 5824.863 lb/jam.ft^2	= 1370608.694 lb/jam.ft^2
pada Tc = 284 ^{o}F	pada tc = 154 ^{o}F
μ = 0.000001 lb/ft.s	μ = 0.000775 lb/ft.s
= 0.004389 lb/ft.jam	= 2.78918 lb/ft.jam
di = 3.07 in	de = 1.14 in
= 0.256 ft	= 0.10 ft
$Nre_p = \dfrac{G_p \times di}{\mu}$	$Nre_{an} = \dfrac{G_{an} \times de}{\mu}$
$= \dfrac{5824.863 \times 0.256}{0.004389}$	$= \dfrac{1370608.6942 \times 0.10}{2.78918}$
= 339320.6	= 46683.2561
2. J_H = - (*steam*)	2'. Menghitung faktor panas (J_H)
	Dari Kern, Fig. 24 Hal.834 didapatka

J_H = 105

3. Menghitung harga koefisien film perpindahan panas
   untuk steam didapatkan:
   h_{io} = 1500 Btu/ft^2.jam^{0}F

3'. Menghitung harga koefisien film
   Dari Kern, Tabel 4 hal.800 didapatka
   k = 0.096647 Btu/jam.ft^2.^{o}F/ft
   Dari Kern, Fig.3 hal.805 didapatkan:
   Cp = 0.227 Btu/lb.^{o}F
   maka,
   $k\,(Cp.\mu/k)^{1/3}$ = 0.1807
   $ho/\varphi s$ = 199.74
   tw = 180.75 ^{o}F
   dimana μ Pada suhu tw didapatkan:
   μw = 0.5804 lb/ft.jam
   μ /μw = 4.805
   Dari Kern, Fig. 24 Hal.834 didapatkan:
   φs = 1.246
   sehingga,
   ho = 248.832 Btu/jam.ft^{2o}F

Clean overall coefficient Uc :

$$U_c = \frac{hio\,.\,ho}{hio + ho} = \frac{1500 \times 248.832}{1500 + 248.832} = 497.665 \text{ Btu/ft}^2\text{.jam}^0\text{F}$$

Dirt factor (faktor kekotoran) pipa terpakai

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

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

$$\frac{1}{U_D} = 0.001 + \frac{1}{497.665}$$

$$\frac{1}{U_D} = 0.003$$

$$U_D = 332.29 \text{ jam.ft}^2\text{.°F/Btu}$$

$$A = \frac{Q}{UD\,.\Delta t} = \frac{275173.5177}{332.29 \times 126.853} = 65.2803 \text{ ft}^2$$

$$L = \frac{A}{a''} = \frac{65.2803}{0.9170} = 71.189 \text{ ft}$$

Mencari panjang ekonomis dengan mencari over design yang terkecil dari pipa standar.

Panjang	Hairpin	pembulatan	L baru	A baru	UD baru	Rd baru	Rd over des

pipa (ft)	(n)	Hairpin	L_{baru}	A_{baru}	U_D baru	R_d baru	(%)
12	2.9662	3	72	66.0240	32.8551	0.028	27.427
15	2.373	3	90	82.5300	26.2841	0.036	35.036
20	1.7797	2	80	73.3600	29.5696	0.032	30.809

Jadi, diambi over desain yang terkecil = 35.036 %

L = 90 ft

n = 3 buah

Evaluasi ΔP

Hot fluid: pipe, Steam

1. Pada Nre p = 339320.57

f = ##### + $\frac{0.264}{(Nre\ p)^{0,42}}$

= ##### + $\frac{0.264}{339320.57^{0,42}}$

= 0.0048

Dari steam tabel, untuk kondisi :

saturated steam

T = 284 °F

P = 45.4 psia

didapatkan, ρ = 0.1073 lb/ft^3

$\Delta Fp = \frac{4.f.Gp^2.L}{2.g.\rho^2.di}$

$= \frac{4 \times \#\#\#\#\# \times 5824.863^2 \times 90}{2 \times 4.18 \times 0.107^2 \times 0.256}$

= 1737.2 ft

$\Delta Pp = \frac{1737.2 \times 0.1073}{144}$

= 1.2945 psi < 2.5 psi

Cold fluid: anulus, liquid product D-12

1'. de' = 0.0442 ft

$Nre_{an} = \frac{G_{an} \times de'}{\mu}$

$= \frac{1370608.6942 \times 0.044}{2.78918}$

= 21703.6190

f = 0.0035 + $\frac{0.264}{(Nre\ an)^{0,42}}$

= 0.0035 + $\frac{0.264}{21703.62^{0,42}}$

= 0.0075

ρ = 28.4824 lb/ft^3

karena panjang pipa,

$\Delta Fa = \frac{4.f.Ga^2.L}{2.g.\rho^2.de'}$

$= \frac{4 \times 0.0075 \times \#\#\#\#\#\#\#\#^2 \times}{2 \times 4.18 \times 28.48^2 \times 0.0}$

= 16.8958 ft

karena tube passes,

$v = \frac{Ga}{3600\rho}$

$= \frac{1370608.7}{3600 \times 28.4824}$

= 13.36703 fps

$Fl = n\left(\frac{v^2}{2gc}\right)$

$= 3\left(\frac{13.367}{2 \times 32.2}\right)$

$= 0.622688$

$\Delta Pa = \frac{(16.896 + 0.623) \times 28.48}{144}$

$= 3.465056$ psi < 10.0 psi

desain memenuhi

Spesifikasi Heater

Fungsi	:	Memanaskan liquida hingga bubble point-nya
Kode alat	:	E-131
Tipe	:	Double pipe Heat Exchanger 4 x 3" sch.40
Bahan Konstruksi	:	Carbon steel SA-135 Grade B
Media pemanas	:	Saturated stean 140 °C , 361.379 kPa
Kapasitas	:	13556.60 kg/jam = 29,886.884 lb/jam
Rate steam	:	135.4097 kg/jam = 298.5242 lb/jam

Dimensi	*Pipe side* , steam				*Anullus side* , Liq.Prod D-12			
	do	=	3.5	in	a_{an}	=	0.0218	ft
	L_{pipe}	=	15	ft	de	=	0.0950	ft
	ap	=	7.38	in^2	de'	=	0.0442	ft
	Hairpin	=	3	buah	L	=	90	ft
	ΔPp	=	1.29	psi	ΔPan	=	3.47	psi

10. Kolom Distilasi (D-130)

Fungsi : Memisahkan produk CCl_4 dari impuritisnya

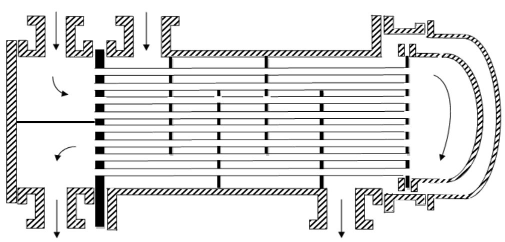
Type : Sieve Tray

Kolom distilasi dirancang oleh Valerie Alpenada (1914002), lihat bab VI Perancangan Alat Utama.

11. Kondensor (E-132)

Fungsi : Menkondensasi top produk dari kolom distilasi D-130

Type : Horizontal Shell and Tube Heat Exchanger



Direncanakan :

- faktor kekotoran gabungan minumum (Rd)	=	0.004	jam.ft².°F/Btu
- Δp maksimum aliran shell	=	10	psi
- Δp maksimum aliran tube	=	2.5	psi

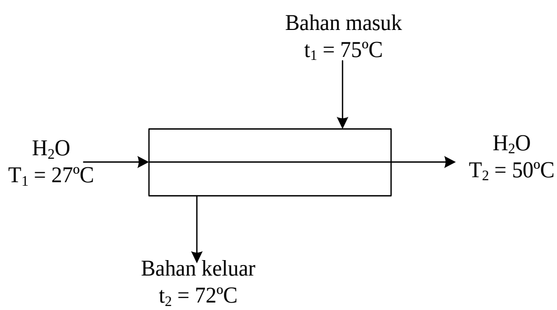
Dasar perencangan :

Dari Appendix B didapatkan data sebagai berikut:

- Massa bahan masuk = 20,913.710 kg/jam
  = 46,106.366 Ib/jam

- Suhu bahan masuk (t_1) = 75 °C = 167.00 °F
- Suhu bahan keluar (t_2) = 72 °C = 161.60 °F
- Kebutuhan pendingin (m) = 405.9817 kg/jam
  = 895.0274 Ib/jam
- Panas yang dibawa coolant = 7,825.6500 kkal/jam
  = 31,034.4623 btu/jam
- H_2O masuk pada suhu (T_1) = 27 °C = 81 °F = 300.15 K
- H_2O keluar pada suhu (T_2) = 50 °C = 122 °F = 323.15 K
- Digunakan pipa ukuran 1 in OD, BWG 16, L = 16 ft, P_T = 1,25 in
- Shell side : Top produk D-130
- Tube side : Cooling water
- Susunan tube segitiga (triangular pitch)

Perhitungan :



A. Menghitung ΔT_{LMTD}

Δt_1 = t2 - T_1 = 162 °F - 81 °F = 81 °F

Δt_2 = t1 -T_2 = 167 °F - 122.00 °F = 45 °F

$$\Delta T_{LMTD} = \frac{\Delta t_1 - \Delta t_2}{\ln \Delta t_1/\Delta t_2}$$ (Kern, Pers.5.14 Hal.89

$$= \frac{81 - 45.00}{\ln(81 / 45.00)}$$

= 61.25 °F

dipilih tipe HE 2-4

B. Menghitung suhu kalorik

Tc = (T_1 + T_2) / 2 = 101 °F = 39 °C = 311.65 K

tc = (t_1 + t_2) / 2 = 164 °F = 73.5 °C = 346.65 K

C. Trial U_D

Dari Kern hal 840 tabel 8 diperoleh:

Range U_D = 2-50 Btu/jam ft^2. ^oF

Dicoba U_D = 20 Btu/jam ft^2. ^oF

Dari App.B didapatkan Q = 141077.67 kkal/jam

= 559840.92 Btu/jam

$$A = \frac{Q}{U_D \cdot \Delta t} = \frac{559840.9203}{20 \times 61.2467} = 2285.188 \text{ ft}^2$$

dengan,

do $_{tube}$ = 1 in

BWG = 16

Dari Kern, tabel 10, hal. 843, diperoleh harga a" = 0.2618 ft^2/ft

$$Nt = \frac{A}{a'' \cdot L} = \frac{2285.1877}{0.2618 \times 12} = 727 \text{ buah}$$

Dari Kern, tabel 9, hal. 842, diperoleh :

IDs = 35 in

n = 4

Nt = 562

$$U_D \text{ koreksi} = \frac{Nt}{Nt \text{ standar}} \times U_D \text{ trial}$$

$$= \frac{727}{562} \times 20 = 25.89 \text{ Btu/jam ft}^2.\ ^oF$$

Dari Kern, tabel 28, hal. 838, diperoleh :

de = 0.72 in

Viskositas aliran pada shell (bahan):

Dari Perry 8th Edition tabel 2-312 Hal. 2-421didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
CS2	5.82E-08	0.9262	44.581		
H_2O	1.71E-08	1.1146			
CCl4	3.137.E-06	0.3742	491.5		

dimana μ dalam Pa.s $\mu = \dfrac{C_1 T^{C2}}{1 + C_3/T + C_4/T^2}$

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
CS2	1021.3393	0.0488359	0.00004	2.6678E-05	1.303E-06
H_2O	19891.222	0.9511092	0.00000	1.0025E-06	9.535E-07
CCl4	1.1487055	5.493E-05	0.03218	0.02162428	1.188E-06
Total	20913.710	1.0000	0.03222	0.0217	0.000003

μ campuran = ∑xi.μi

$$= \frac{0.000003}{1.0000} = 0.000003 \text{ lb/ft.s} = 0.012399 \text{ lb/ft.jam}$$

(∑xi)

Viskositas aliran pada pipe (cooling water):

Dari Perry 8th Edition tabel 2-313Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
H_2O	-52.84300	3703.6000	5.8660	-5.9.E-29	10

dimana μ dalam Pa.s

$$\mu = \exp(C1 + C2/T + C3\ln T + C4T^{C5}$$

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
H_2O	895.0274	1.0000	0.00069	0.000464	0.000464

Densitas aliran pada shell (bahan):

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
CS2	76	1.79680	0.28749	552.000	0.32260
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06
CCl4	154	0.99835	0.27400	556.3500	0.28700

dimana, ρ dalam mol/m^3

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
CS2	1021.3393	0.0488	237.1006	11.5790
H_2O	1.1487055	0.0001	54.4783	0.0030
CCl4	19891.222	0.9511	256.4432	243.9055
Total	20913.71	1.0000	548.0221	255.4875

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

$$= \frac{255.4875}{1.0000} = 255.4875 \text{ kg/m}^3 = 15.94242 \text{ lb/ft}^3$$

Densitas aliran pada tube (cooling water):

Komponen	berat molekul	C1	C2	C3	C4
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06

dimana, ρ dalam mol/m^3 $\rho = C_1 + C_2T + C_3T^2 + C_4T^3$

Komponen	Massa	xi (massa)	ρ (kg/m^3)	ρ (lb/ft^3)	xi.ρi

Komponen	(Kg/jam)	xi (massa)	ρ (kg/m³)	ρ (lb/ft³)	xi.ρi
H_2O	405.9817	1.0000	996.0587	65.9817	65.9817
Total	405.98175	1.0000	996.0587	65.9817	65.9817

Kesimpulan sementara hasil perancangan :

Type HE : 2-4

Bagian *Tube*

do = 1 in, 16 BWG

L = 16 ft Nt = 562

Susunan segitiga, n = 4

di = 0.8700 in = 0.073 ft

a' = 0.5940 in^2 = 0.050 ft^2

a" = 0.2618 ft^2/ft

Pt = 1.25 in

Bagian *Shell*

IDs = 35 in = 2.92 ft

n' = 2

B = 28 in = 2.33 ft

de = 0.72 in = 0.06 ft

C' = 1 1/4 - 1 = 0.25

Evaluasi Perpindahan Panas

Cold fluid: tube, cooling water

1. Menghitung NRe

$$a_t = \frac{Nt \times a'}{n \times 144}$$

$$= \frac{562 \times 0.050}{4 \times 144}$$

$$= 0.0483 \ ft^2$$

$$G_t = \frac{m}{a_t}$$

$$= \frac{895.0274 \ lb/jam}{0.0483 \ ft^2}$$

$$= 18531.786 \ lb/jam.ft^2$$

pada Tc = 101 °F

μ = 0.000464 lb/ft.s

= 1.670887 lb/ft.jam

di = 0.87 in

= 0.073 ft

$$N_{re\ p} = \frac{G_t \times di}{\mu}$$

$$= \frac{18531.79 \times 0.073}{1.670887}$$

$$= 804.0967$$

Velocity

$$v = \frac{G_t}{}$$

Hot fluid: shell, Top product D-130

1'. Menghitung NRe

$$a_s = \frac{IDs \times C' \times B}{n' \times Pt \times 144}$$

$$= \frac{2.917 \times 0.25 \times 28}{2 \times 1.25 \times 144}$$

$$= 0.05671 \ ft^2$$

$$G_s = \frac{M}{a_s}$$

$$= \frac{46106.366 \ lb/jam}{0.0567 \ ft^2}$$

$$= 812977.5496 \ lb/jam.ft^2$$

pada tc = 164 °F

μ = 0.000003 lb/ft.s

= 0.01240 lb/ft.jam

de = 0.72 in

= 0.06 ft

$$Nre_s = \frac{G_{an} \ x \ de}{\mu}$$

$$= \frac{812977.5496 \times 0.06}{0.01240}$$

$$= 3934164.8685$$

2'. Menghitung harga koefisien film

$$= \frac{18531.79}{3600 \times 65.982} \quad (3600\rho)$$

$= 0.7801735$ fps

2. Menghitung harga koefisien film perpindahan panas
   Dari Kern, Fig. 25 Hal.835 , didapatkan:
   hi = 480 Btu/jam.ft^{2o}F
   faktor koreksi = 0.94
   sehingga,

$$hio = hi \left(\frac{di}{do}\right)$$

$$= 451.2 \left(\frac{0.8700}{1.00}\right)$$

$= 392.54$ Btu/jam.ft^{2o}F

Untuk condensor horizontal,
ho berkisar 150-300 Btu/jam.ft^2 ^{o}F

Trial ho = 300 Btu/jam.ft^{2o}F

$$tw = tc + \frac{ho}{ho + hio}\left(Tc\text{-}tc\right)$$

$$= 164 + \frac{300}{300 + 393}\left(101 + 16\right.$$

$= 279.354$ ^{o}F

$$tf = \frac{Tc + tw}{2} = \frac{101.3 + 279.4}{2}$$

$= 190$ ^{o}F

sehingga,
Dari Kern, Tabel 4 hal.800 didapatkan:
kf = 0.42152 Btu/jam.ft^2.^{o}F/ft

Dari Kern, Tabel 6 hal.808 didapatkan:
sf = 1.01273 Btu/jam.ft^2.^{o}F/ft
Dari Kern, Fig.14hal.823 didapatkan:
μf = 0.14196 cp

$$G'' = \frac{M}{L \ Nt^{2/3}}$$

$$= \frac{46{,}106.366}{16 \times 562^{2/3}}$$

$= 42.3139$ lb/jam.ft
Dari Kern, Fig.12.9 hal.267 didapatkan:
ho = 310

$$\varepsilon = \frac{310 - 300}{300}$$

$= 3\% < 10\%$ *ho memenuhi*

Clean overall coefficient Uc :

$$U_c = \frac{hio \cdot ho}{hio + ho} = \frac{393 \times 310}{393 + 310} = 620.00 \ \text{Btu/ft}^2.\text{jam}^0\text{F}$$

Dirt factor (faktor kekotoran) pipa terpakai

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

$$= \frac{620 - 25.9}{620 \times 25.9} = 0.03702 \ \text{jam.ft}^2.^\circ\text{F/Btu}$$

Karena harga Rd hitung > Rd tetapan, maka rancangan HE memenuhi.

Evaluasi ΔP

Cold fluid: tube, cooling water	Hot fluid: shell, Top product D-130
1. Pada NRe_t = 804.0967	1'. Pada Nres = 3934164.8685
Dari Kern,fig. 26 hal.836,	Dari Kern,fig. 29 hal.839, diperoleh:
diperoleh: f = 0.00045	f = 0.0030
sg = 1	2'. No. of crosess
	$(N+1) = \frac{12L}{B} = \frac{12 \times 16}{28}$
2. ΔP karena panjang pipa :	= 6.86
$\Delta Pl = \frac{1}{2} \cdot \frac{f.Gt^2.L.n}{5{,}22\times10^{10}.di.sg.\phi}$	Dari Kern,Tabel 6 hal.808, diperoleh:
$= \frac{0.00045 \times 18531.8^2 \times 16 \times 4}{2 \times 5{,}22.10^{10} \times 0.073 \times 1.00 \times 1}$	$sg = \frac{\rho}{62.5}$
= 0.0013 psi	$= \frac{15.94242}{62.5}$
	= 0.25507873
ΔP karena tube passes	4'. $\Delta Ps = \frac{f.Gs^2.IDs.(N+1)}{5{,}22\times10^{10}.de.sg.\phi}$
Dari Kern,fig. 27 hal.837,diperoleh:	
$\left[\frac{v^2}{2gc}\right]\frac{\rho}{144}$ = 0.001 , sehingga	$= \frac{0.003 \times 812977.5^2 \times 2.92 \times 7}{5{,}22\times10^{10} \times 0.06 \times 0.255 \times 0.97}$
$\Delta Pn = \frac{4n}{sg}\left[\frac{v^2}{2gc}\right]\frac{\rho}{144}$	= 5.1173 psi < 10.0 psi
$= \frac{4 \times 4}{1.0000} \times 0.001$	*desain memenuhi*
= 0.016 psi	
sehingga,	
ΔPt total = 0.0013 + 0.016	
= 0.02 psi < 2.5 psi	
desain memenuhi	

Spesifikasi Kondensor

Fungsi	:	Menkondensasi top produk dari kolom distilasi D-130
Kode alat	:	E-132
Tipe	:	Horizontal Shell and Tube Heat Exchanger
Bahan Konstruksi	:	Carbon steel SA-135 Grade B
Media pendingin	:	Cooling water 27 °C ,
Kapasitas	:	20,913.710 kg/jam = 46,106.366 lb/jam
Rate pendingin	:	405.9817 kg/jam = 895.0274 lb/jam
Dimensi		*Tube side* , cooling water

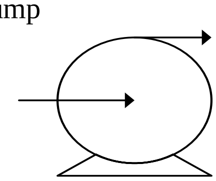
Tube side, cooling water	*Shell side*, Top product D-13
do = 1 in 16 BWG	IDs = 35 in = 2.92
di = 0.87 in	B = 28 in
L = 16 ft	de = 0.72 in
Nt = 562	C' = 0.25 in

Pt = 1.25 in ΔPs = 5.12 psi
Tringular Pitch
ΔPt = 0.02 psi

12. Pompa sentrifugal (L-134d)

Fungsi : Untuk mengalirkan produk destilat dari kolom distilasi (D-130) menuju storage (F-136)

Tipe : Centrifugal pump



Direncanakan :

Bahan konstruksi = Carbon steel

Jumlah = 1 buah

Kondisi operasi :

Suhu (T) = 78.8 ^oC = 351.99 K

Tekanan (P) = 1 atm = 14.7 psia = 0 psig

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
CS2	76	1.79680	0.28749	552.000	0.32260
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06
CCl4	154	0.99835	0.27400	556.3500	0.28700

dimana, ρ dalam mol/m^3

$$\rho = \frac{C_1}{C_2^{\left(1 + \left(1 - \frac{T}{C_3}\right)^{C_4}\right)}}$$

untuk water mengunakan persamaan:

$$\rho = C_1 + C_2 T + C_3 T^2 + C_4 T^3$$

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
CS2	0.3978545	0.0001	236.1800	0.0136
H_2O	0.3978545	0.0001	977.9801	0.0565
CCl4	6889.3313	0.9999	255.5303	255.5008
Total	6890.127	1.0000	1469.6904	255.5709

$$\rho \text{ campuran} = \frac{255.5709}{1.0000} = 255.5709 \text{ kg/m}^3 = 15.94762 \text{ lb/ft}^3$$

Dari Perry 8th Edition tabel 2-313 Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
CS2	-10.3060	703.01			
H_2O	-52.8430	3703.6	5.866	-5.88E-29	10
CCl4	-8.0738	1121.1	-0.4726		

dimana μ dalam Pa.s $\mu = \exp(C1 + C2/T + C3\ln T + C4T^{C5}$

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
CS2	353.7412	0.0488359	0.00025	0.00016554	8.084E-06
H_2O	0.3978545	5.493E-05	0.00036	0.00024251	1.332E-08
CCl4	6889.3313	0.9511092	0.00047	0.00031673	0.0003012
Total	7243.4704	1.0000	0.00108	0.0007	0.0003093

μ campuran = $\frac{\sum xi.\mu i}{\sum xi}$

= $\frac{0.000309}{1.0000}$ = 0.0003093 lb/ft.s = 1.113647 lb/ft.jam

Rate bahan masuk (m) = 7243.4704 kg/jam

= 15968.955 lb/jam

PERHITUNGAN :

A. Menghitung Rate Volumetrik (Q)

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

= $\frac{15968.955}{15.9476}$

= 1001.3376 ft^3/jam

= 0.2781 ft^3/s

= 124.8432 gpm

Di $_{optimum}$ = $3{,}9\ Q^{0{,}45} \times \rho^{0{,}13}$ (Pers.15 "Petters&Timmerhaus",hal 496)

= $3.9 \times 0.2781^{0{,}45} \times 15.9476^{0{,}13}$

= 3.1430 ≈ 3 in

= 0.2500 ft

Untuk pipa ukuran 3 in sch 40

Dari Brownell and Young, App.K-2 Hal.387 didapatkan:

OD = 3.500 in = 0.2917 ft
ID = 3.068 in = 0.2557 ft
A = 0.05132 ft^2

B. Menentukan Kecepatan Aliran Fluida (v)

Kecepatan aliran fluida $= \frac{Q}{A}$

$= \frac{1001.3376}{0.05132}$

= 19511.8684 ft/jam
= 5.4200 ft/s

C. Menentukan Bilangan Reynold

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

$= \frac{0.25567 \times 5.4200 \times 15.9476}{0.000309}$

= 71436.727 $\geq$ 4000 (aliran turbulen)

DariGeankoplis, Fig. 2.10-3 Hal. 88 didapatkan:

Equivalent rougness(ε) = 4.6E-05 m

Relative rougness $\frac{\varepsilon}{D}$ = 0.0006

Faktor friksi (f) = 0.0065
α = 1

D. Menentukan Panjang Pipa

Asumsi :

- Panjang pipa lurus = 150 ft
- elbow 90^o = 3 buah
  Le/D = 35 (Geankoplis,Tabel 2-10.1 Hal 93)
  L elbow = 35 ID
  = 35 × 3 × 0.29167 ft
  = 30.625 ft
- Globe valve = 1 buah
  Le/D = 300 (Geankoplis,Tabel 2-10.1 Hal 93)
  L elbow = 300 ID
  = 300 × 1 × 0.29167 ft
  = 87.500 ft

Panjang pipa total (L) = Pipa lurus + elbow 90^o + globe valve
= 150 + 30.625 + 87.500
= 268.125 ft
= 3218 in

E. Menentukan friksion Loss

1. Friksi pada pipa lurus

$F_f = 4f \dfrac{\Delta L}{D} \times \dfrac{v^2}{2g_c}$ (Geankoplis, Pers.2-10.6 Hal 86)

$= 4 \times 0.0065 \dfrac{268.1250}{0.2556667} \times \dfrac{5.4200^2}{2 \times 32.2}$

$= 12.4478$ lbf.ft/lbm

2. Kontraksi pada keluaran tangki

$hc = Kc \dfrac{v^2}{2g_c}$ (Geankoplis, Pers.2-10.16 Hal 93)

$= 0.55 \dfrac{5.4200^2}{2 \times 32.174}$

$= 0.2511$ lbf.ft/lbm

3. Elbow 90°, 2 buah

$K_f = 0.75$ (Geankoplis, Tabel 2.10-1 Hal. 93

$hf = 2Kf \dfrac{v^2}{2g_c}$ (Geankoplis, Pers.2-10.17 Hal 94)

$= 2 \times 0.75 \dfrac{5.4200^2}{2 \times 32.174}$

$= 0.6848$ lbf.ft/lbm

Total friksi ($\sum F$) $= 12.4478 + 0.2511 + 0.684777$

$= 13.3837$ lbf.ft/lbm

F. Menentukan Kesetimbangan Mekanik

Direncanakan:

ΔZ = 30 ft

ΔP = 0 lb/ft^2

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

v_2 = 5.420 ft/s

α = 1 (aliran turbulen)

Sehingga Mechanical energy balance :

$\dfrac{V_2 - V_1}{2.\alpha.gc} + \Delta Z \dfrac{g}{gc} + \dfrac{\Delta P}{\rho} + \sum F = - Ws$

$\dfrac{5.4200 - 0}{} + 30 \dfrac{32.17}{} + 13.3837 = - Ws$

2 × 1 × 32.17 + 30 32.17 + 15.5837 = - Ws

-Ws = 43.4679 lbf.ft/s

Dengan: Capacity = 124.84 gal/menit

μ campuran = 1.0786 Centipoise

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

Efisiensi pompa (η) = 90%

Ws = - η Wp

43.4679 = - 90% Wp

Wp = 48.2977 ft.lbf/s

mass flow rate (m) = Q x ρ

= 1001.3376 × 15.9476

= 15968.955 lbm/jam

= 4.4358 lbm/s

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

$$WHp = 48.2977 \times 4.4358 \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

WHp = 0.3895 hp

$$BHp = \frac{WHp}{\eta} = \frac{0.3895}{90\%} = 0.4328 \text{ Hp}$$

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

Efisiensi motor = 90%

$$\text{Daya} = \frac{\text{pump horsepower}}{\text{efisiensi motor}} = \frac{0.4328}{90\%} = 0.4809 \text{ Hp} \approx 1 \text{ Hp}$$

Spesifikasi Pompa Sentrifugal

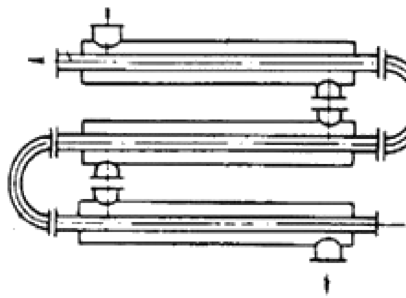
Fungsi	:	Untuk mengalirkan top product dari kolom distilasi (D-130) menuju storage (F-136)
Kode alat	:	L-134d
Tipe	:	Centrifugal pump
Kapasitas	:	124.84 gpm
Suhu operasi	:	351.99 K
Tekanan operasi	:	1 atm
Efisiensi Pompa	:	90%
ΔP	:	0 lb/ft^2
Bahan Konstruksi	:	Carbon steel
Daya	:	1 Hp
Dimensi		

NPS	:	3	in	OD	:	3.500	in	A	:	0.05132 ft^2
Sch	:	40		ID	:	3.068	in			

13. Cooler (E-135 a)

Fungsi : Untuk mendinginkan produk destilat ke 30 ^oC

Type : Double Pipe Heat Exchanger



Direncanakan :

faktor kekotoran gabungan minimum (Rd) = 0.001 jam.$ft^{2}.^{0}F$/Btu

Δp maksimum aliran = 10 psi

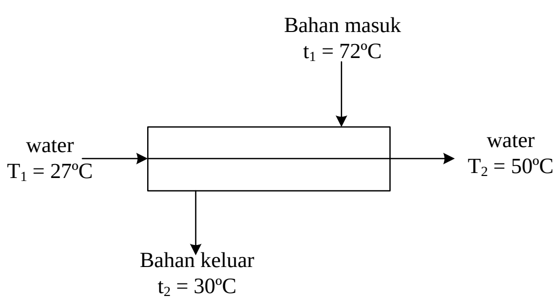
Δp maksimum steam = 2.5 psi

Dasar perencangan :

Dari Appendix B didapatkan data sebagai berikut:

- Massa bahan masuk = 7,243.470 kg/jam
  = 15,968.955 Ib/jam
- Suhu bahan masuk (t_1) = 72 ^oC = 161.60 ^oF
- Suhu bahan keluar (t_2) = 30 ^oC = 86.00 ^oF
- Kebutuhan pendingin (m) = 220.5729 kg/jam
  = 486.2751 Ib/jam
- Panas yang dibawa coolant = 40,934.3633 kkal/jam
  = 162,334.8797 btu/jam
- water masuk pada suhu (T_1) = 27 ^oC = 81 ^oF = 300.15 K
- water keluar pada suhu (T_2) = 50 ^oC = 122 ^oF = 323.15 K

Perhitungan :



1. Menghitung Δt

$\Delta t_1 = t_1 - T_2 = 162 - 122 = 39.6\ ^0F$

$\Delta t_2 = t2 - T1 = 86 - 81 = 5.4\ ^0F$

$$\Delta T_{LMTD} = \frac{\Delta t_1 - \Delta t_2}{\ln \frac{\Delta t1}{\Delta t2}} = \frac{39.6 - 5.4}{\ln \frac{39.6}{5.4}} = 17.165\ ^0F$$

2. Menghitung suhu caloric (Tc dan tc)

$Tc = (T_1 + T_2) / = 101\ ^oF = 39\ ^0C = 311.65\ K$

$tc = (t_1 + t_2) / 2 = 124\ ^oF = 51\ ^0C = 324.15\ K$

Viskositas aliran pada anulus (bahan):

Dari Perry 8th Edition tabel 2-313 Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
CS2	-10.3060	703.01			
H_2O	-52.8430	3703.6	5.866	-5.88E-29	10
CCl4	-8.0738	1121.1	-0.4726		

dimana μ dalam Pa.s $\mu = \exp(C1 + C2/T + C3 \ln T + C4T^{C5}$

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
CS2	353.7412	0.0488359	0.00029	0.00019652	9.597E-06
H_2O	0.3978545	5.493E-05	0.00055	0.00036957	2.03E-08
CCl4	6889.3313	0.9511092	0.00064	0.00043292	0.0004118
Total	7243.4704	1.0000	0.00149	0.0010	0.000421

$$\mu \text{ campuran} = \frac{\sum xi.\mu i}{\sum xi}$$

$$= \frac{0.000421}{1.0000} = 0.000421 \text{ lb/ft.s} = 1.516938 \text{ lb/ft.jam}$$

Viskositas aliran pada pipe (cooling water):

Dari Perry 8th Edition tabel 2-313Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
H_2O	-52.84300	3703.6000	5.8660	-5.9.E-29	10

dimana μ dalam Pa.s

$\mu = \exp(C1 + C2/T + C3 \ln T + C4T^{C5}$

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi

H_2O	220.5729	1.0000	0.00069	0.000464	0.000464

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
CS2	76	1.79680	0.28749	552.000	0.32260
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06
CCl4	154	0.99835	0.27400	556.3500	0.28700

dimana, ρ dalam mol/m^3

$$\rho = \frac{C_1}{C_2^{(1+(1-\frac{T}{C_3})^{C_4}}}$$

untuk water mengunakan persamaan:

$$\rho = C_1 + C_2T + C_3T^2 + C_4T^3$$

Densitas aliran pada anulus (bahan):

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
CS2	353.7412	0.0488	241.0191	11.7704
H_2O	0.3978545	0.0001	991.1529	0.0544
CCl4	6889.3313	0.9511	260.3258	247.5982
Total	7243.4704	1.0000	1492.4978	259.4231

$$\rho \text{ campuran} = \frac{259.4231}{1.0000} = 259.4231 \text{ kg/m}^3 = 16.18800 \text{ lb/ft}^3$$

Trial ukuran DPHE

Dicoba ukuran DPHE : 4x 3" IPS sch.40 dengan aliran cooling water di bagian

Dari Kern, tabel 6.2 hal.110 didapatkan :

a_{an} = 3.14 in^2 = 0.0218 ft^2

a_p = 7.38 in^2 = 0.0513 ft^2

de = 1.14 in = 0.0950 ft

de' = 0.53 in = 0.0442 ft

Dari Kern, tabel 11 hal.844 didapatkan :

dop = 3.5 in = 0.0243 ft

dip = 3.07 in = 0.2557 ft

a" = 0.92 ft^2/ft

Evaluasi Perpindahan Panas

Cold fluid: pipe, cooling water	Hot fluid: anulus, destilat D-130
1. Menghitung NRe	1'. Menghitung NRe
$G_p = \frac{M}{a_p}$	$G_{an} = \frac{m}{a_{an}}$
$= \frac{486.2751 \text{ lb/jam}}{0.0513 \text{ ft}^2}$	$= \frac{15968.955 \text{ lb/jam}}{0.0218 \text{ ft}^2}$
$= 9488.294$ lb/jam.ft^2	$= 732334.231$ lb/jam.ft^2
pada Tc = 101 ^{o}F	pada tc = 124 ^{o}F
μ = 0.000464 lb/ft.s	μ = 0.000421 lb/ft.s
= 1.670887 lb/ft.jam	= 1.51694 lb/ft.jam
di = 3.07 in	de = 1.14 in
= 0.256 ft	= 0.10 ft
$Nre_p = \frac{G_p \times di}{\mu}$	$Nre_{an} = \frac{G_{an} \text{ x } de}{\mu}$
$= \frac{9488.294 \times 0.26}{1.670887}$	$= \frac{732334.2311 \times 0.10}{1.51694}$
= 1451.8282	= 45863.2754
2. Velocity	2'. Menghitung faktor panas (J_H)
$v = \frac{G_p}{3600\rho}$	Dari Kern, Fig. 24 Hal.834 didapatka
$= \frac{9488.29}{3600 \times 61.916}$	J_H = 100
= 4.2567676 fps	
3. Menghitung harga koefisien film perpindahan panas	3'. Menghitung harga koefisien film
Dari Kern, Fig. 25 Hal.835 , didapatkan:	Dari Kern, Tabel 4 hal.800 didapatka
	k = 0.093967 Btu/jam.ft^2.^{o}F/ft
	Dari Kern, Fig.3 hal.805 didapatkan:
hi = 320 Btu/jam.ft^{2o}F	Cp = 0.211 Btu/lb.^{o}F
faktor koreksi = 1.1	maka,
sehingga,	$k\,(Cp.\mu/k)^{1/3}$ = 0.1414
$hic = hi \left(\frac{di}{do}\right)$	$ho/\varphi s$ = 148.83
	tw = 124.67 ^{o}F
$= 352 \left(\frac{0.2557}{0.0243}\right)$	dimana μ Pada suhu tw didapatkan:
	μw = 0.7060 lb/ft.jam
= 3702.6 Btu/jam.ft^{2o}F	$\mu/\mu w$ = 2.149
	Dari Kern, Fig. 24 Hal.834 didapatkan:
	φs = 1.113
	sehingga,
	ho = 165.652 Btu/jam.ft^{2o}F

Clean overall coefficient Uc :

$$U_c = \frac{hio\ .\ ho}{hio + ho} = \frac{3703 \times 165.652}{3703 + 165.652} = 331.303\ \text{Btu/ft}^2.\text{jam}^0\text{F}$$

Dirt factor (faktor kekotoran) pipa terpakai

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

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

$$\frac{1}{U_D} = 0.001 + \frac{1}{331.303}$$

$$\frac{1}{U_D} = 0.004$$

$$U_D = 248.86\ \text{jam.ft}^2.°\text{F/Btu}$$

$$A = \frac{Q}{UD\ .\Delta t} = \frac{162334.8797}{248.86 \times 17.165} = 38.003\ \text{ft}^2$$

$$L = \frac{A}{a''} = \frac{38.003}{0.9170} = 41.443\ \text{ft}$$

Mencari panjang ekonomis dengan mencari over design yang terkecil dari pipa standar.

Panjang pipa (ft)	Hairpin (n)	pembulatan Hairpin	L_{baru}	A baru	UD baru	Rd baru	Rd over des (%)
12	1.7268	2	48	44.0160	214.861	0.002	0.636
15	1.3814	2	60	55.0200	171.889	0.003	1.799
20	1.0361	2	80	73.3600	128.917	0.005	3.739

Jadi, diambi over desain yang terkecil = 0.636 %

L = 48 ft

n = 2 buah

Evaluasi ΔP

Cold fluid: pipe, cooling water

1. Pada Nre p = 1451.83

$$f = \#\#\#\#\# + \frac{0.264}{(Nre\ p)^{0,42}}$$

$$= \#\#\#\#\# + \frac{0.264}{1451.83^{0,42}}$$

$$= 0.0159$$

Dari Geankoplis, tabel.A-23 Hal.855 didapatkan:

ρ = 992.25 kg/m^3

= 61.916 lb/ft^3

$$\Delta Fp = \frac{4.f.Gp^2.L}{}$$

Hot fluid: anulus, destilat D-130

1'. de' = 0.0442 ft

$$Nre_{an} = \frac{G_{an} \times de'}{\mu}$$

$$= \frac{732334.2311 \times 0.044}{1.51694}$$

$$= 21322.4000$$

$$f = 0.0035 + \frac{0.264}{(Nre\ an)^{0,42}}$$

$$= 0.0035 + \frac{0.264}{21322.40^{0,42}}$$

$$= 0.0075$$

ρ = 16.1880 lb/ft^3

$2.g.\rho^2.di$

$= \frac{4 \times ##### \times 9488.294^2 \times 48}{2 \times 4.18 \times 61.92^2 \times 0.256}$

$= 0.0074$ ft

$\Delta Pp = \frac{0.0074 \times 61.916}{144}$

$= 0.0032$ psi < 2.5 psi

karena panjang pipa,

$\Delta Fa = \frac{4.f.Ga^2.L}{2.g.\rho^2.de'}$

$= \frac{4 \times 0.0075 \times 732334.2^2 \times}{2 \times 4.18 \times 16.19^2 \times 0.0}$

$= 79.95739$ ft

karena tube passes,

$v = \frac{Ga}{3600\rho}$

$= \frac{732334.2}{3600 \times 16.1880}$

$= 12.56648$ fps

$Fl = n\left(\frac{v^2}{2gc}\right)$

$= 2\left(\frac{12.566}{2 \times 32.2}\right)$

$= 0.390263$

$\Delta Pa = \frac{(79.957 + 0.390) \times 16.19}{144}$

$= 9.032416$ psi < 10.0 psi

desain memenuhi

Spesifikasi Cooler

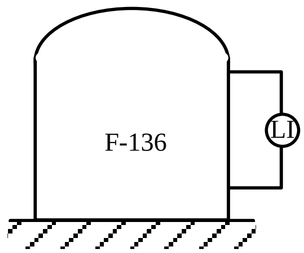
Fungsi	:	Untuk mendinginkan produk destilat ke 30 ^oC
Kode alat	:	E-135
Tipe	:	Double pipe Heat Exchanger 4 x 3" sch.40
Bahan Konstruksi	:	Carbon steel SA-135 Grade B
Media pendingin	:	Cooling water 27 ^oC ,
Kapasitas	:	7,243.4704 kg/jam = 15,968.955 lb/jam
Rate steam	:	220.5729 kg/jam = 486.2751 lb/jam
Dimensi		*Pipe side* , cooling water *Anullus side* , destilat D-130

do	=	3.5	in	a_{an}	=	0.0218	ft
L_{pipe}	=	12	ft	de	=	0.0950	ft
ap	=	7.38	in^2	de'	=	0.0442	ft
Hairpin	=	2	buah	L	=	48	ft
ΔPp	=	0.0032	psi	ΔPan	=	9.03	psi

14. Storage Tank Karbon Tetrachlorida (F-136)

Fungsi : Untuk menampung produk karbon tetrachlorida

Tipe : Tangki bentuk silinder tegak dengan tutup atas berbentuk standard dished dan dasar berbentuk datar (flat bottom)



Direncanakan :

Bahan konstruksi = Carbon steels SA-135 Grade B

Allowable stress (*f*) = 12750 psi

Tipe pengelasan = Double welded but joint (E = 0.8)

Faktor korosi (C) = 1/16 in

Waktu tinggal = 7 hari

Volume ruang kosong = 20% Volume total

Jumlah tangki = 2 buah

Kondisi operasi :

Suhu operasi = 27 ^oC = 300.15 K

Tekanan operasi = 1 atm = 14.7 psia = 0 psig

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
CS2	76	1.79680	0.28749	552.000	0.32260
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06
CCl4	154	0.99835	0.27400	556.3500	0.28700

dimana, ρ dalam mol/m^3

$$\rho = \frac{C_1}{C_2^{\left(1 + \left(1 - \frac{T}{C_3}\right)^{C_4}\right)}}$$

untuk water mengunakan persamaan:

$$\rho = C_1 + C_2 T + C_3 T^2 + C_4 T^3$$

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
CS2	353.7412	0.0488	245.2703	11.9780

H_2O	0.3978545	0.0001	999.5509	0.0549
CCl4	6889.3313	0.9511	264.5320	251.5988
Total	7243.4704	1.0000	1509.3532	263.6317

ρ campuran = $\frac{263.6317}{1.0000}$ = 263.6317 kg/m^3 = 16.45062 lb/ft^3

Rate bahan masuk (m) = 7243.4704 kg/jam

= 15968.955 lb/jam

PERHITUNGAN

A. Menghitung Volume Tangki

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

= $\frac{7243.4704 \text{ kg/jam}}{263.6317 \text{ kg/m}^3} \times \frac{24 \text{ jam}}{1 \text{ hari}} \times$ 7 hari

= 4615.9205 m^3

Jumlah produk carbon tetrachloride yang harus disimpan dalam 7 hari sebanya 4615.9205 m^3 yang disimpan didala 2 buah tangki storage dimana jika disimpan dalam 1 buah tangki akan membutuhkan volume yang terlalu besar. sehingga,

Volume = $\frac{4615.9205}{2}$ = 2307.96023 m^3

Volume tangki = $\frac{2307.9602}{0.8}$ = 2884.95029 m^3

B. Menentukan Dimensi tangki

Asumsi Ls = 2 di

Volume tanki = Volume silinder + Tutup atas

2884.9503 = $\frac{\pi}{4} di^2 Ls$ + 0,0847 di^3

2884.9503 = $\frac{\pi}{4} di^2 \times 1,5di$ + 0,0847di^3

2884.9503 = 1.8144 di^3

di^3 = 1590.0299

di = 11.6717 m = 459.5170 in = 38.2926 ft

C. Menghitung Tinggi Liquida

Tinggi liquida (HL) = $\frac{\text{Volume liquida}}{\frac{1}{}\pi \times di^2}$

$$= \frac{2307.9602}{\frac{1}{4} \times 3.14 \times 11.6717^2}$$

= 21.5818 m = 849.6792 in = 70.8057 ft

D. Menentukan Tekanan Design (Pi)

Tekanan hidrostatik (Ph) $= \frac{\rho\,(HL-1)}{144}$

$= \frac{16.4506 \times (70.8057 - 1)}{144}$

= 7.9746 psia

= 22.6746 psig

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

= 14.7 + 22.6746

= 37.3746 psig

= 2.5769 bar

E. Menghitung Tebal Silinder (ts)

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

$= \frac{37.3746 \times 459.5170}{2\,(12750 \times 0.8 - 0.6 \times 37.3746)} + \frac{1}{1}$

$= 0.9053 \times \frac{16}{16}$

ts $= \frac{14.4848}{16}$ in $\approx \frac{5}{16}$ in

do = di + 2(ts)

= 459.5170 + 2(1/3)

= 460.1420 in ≈ 240 in

Berdasarkan "Brownel and Young" tabel 5.7 hal 90, didapatkan :

icr = 14 7/16 in

r = 180 in

di_{baru} = do_{st} - 2ts

= 240 - 2(1/3)

= 239.375 in

= 19.9479 ft

F. Menghitung Tinggi Silinder (Ls)

Tinggi silinder (Ls) = 2.2 × di

= 2.2 × 19.9479 ft

= 43.8854 ft

= 526.625 in

G. Menghitung Dimensi Tutup Atas Dan Tutup Bawah

Bentuk tutup atas adalah standar dish dan tutup bawah adalah flat, sehingga :

r = di_{baru}

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

$= \dfrac{0.885 \times 37.3746 \times 239.375}{2\ (\ 12750 \times 0.8 - 0.1 \times 37.3746\ )} + \dfrac{1}{1}$

$= 0.4508 \times \dfrac{16}{16}$

$= \dfrac{7.2122}{16} \approx 5/16$ in

Tinggi Tutup atas = 0.169 × di

= 0.169 × 239.3750 in

= 40.4544 in

H. Menghitung Tinggi Tangki (H)

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

= 526.625 + 40.4544

= 567.0794 in

= 47.2566 ft

G. Desain Bagian Bawah Tangki

Untuk mempermudah pengelasan dan memperhitungkan terjadinya korosi, mal pada lantai (bottom) dipakai plat dengan tebal minimal 1/2 in. Tegangan yang bekerja pada plat yang digunakan pada lantai harus diperiksa agar diketahui apakah plat yang digunakan telah memenuhi persyaratan atau tidak.

Tegangan yang bekerja pada bottom:

1. Compressive stress yang dihasilkan oleh carbon tetrachloride.

$S_1 = \dfrac{\sum liquid\ wt}{12\ \pi D_m (t_s - c)}$ (Brownell,1959. Pers.9-5 Hal 157

Dimana:

ts : tebal shell, in

Dm : diameter shell, ft

liquid wt dalam lb

$S_1 = \dfrac{15968.9548}{12 \times 3.14 \times 19.9479\ (\ 1/3 - 1/16\ )}$

S_1 = 84.9822 psi

2. Compressive stress yang dihasilkan oleh berat shell.

$$S_2 = \frac{X\rho_s}{144}$$ (Brownell,1959. Pers.9-3 Hal 156

Dimana:

X : tinggi tangki, ft

ρ_s : densitas material shel 490 lb/ft^3 untuk material steel

$$S_2 = \frac{47.2566 \times 490}{144}$$

$= 160.8$ psi

Tegangan total yang bekerja pada lantai:

$S_t = S_1 + S_2$

$= 84.9822 + 160.80376$

$= 245.7860$ psi

Batas tegangan lantai yang diizinkan:

$S_t < f.E$

$245.7860 < 12750 \times 0.8$

$245.7860 < 10200$ sehingga memenuhi

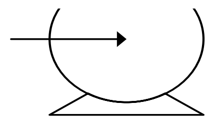
Spesifikasi Storage Tank Karbon Tetraklorida

Fungsi	:	Untuk menampung produk karbon tetraklorida
Kode alat	:	F-136
Tipe	:	Silinder tegak dengan tutup bawah berbentuk flat bottom dan tutup bawah berbentuk standard dished
Kapasitas	:	2884.9503 m^3
Suhu operasi	:	300.15 K
Tekanan operasi	:	1 atm
Dimensi		
Diameter shell	:	20.0000 ft
Tinggi shell	:	43.8854 ft
Tebal shell	:	1/3 in
Tinggi atap	:	3.3712 ft
Tebal atap	:	1/3 in
Tipe pengelasan	:	Double welded but joint (E = 0.8)
Bahan Konstruksi	:	Carbon steels SA-135 Grade B
Jumlah	:	2 buah

15. Pompa Sentrifugal (L-134b)

Fungsi : Untuk mengalirkan bottom product kolom distilasi (D-130) menuju reboiler (E-133)

Tipe : Centrifugal pump



Direncanakan :

Bahan konstruksi = Carbon steel

Jumlah = 1 buah

Kondisi operasi :

Suhu (T) = 135 ^oC = 408.15 K

Tekanan (P) = 1 atm = 14.7 psia = 0 psig

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06
CCl4	154	0.99835	0.27400	556.3500	0.28700

dimana, ρ dalam mol/m^3

$$\rho = \frac{C_1}{C_2^{(1 + (1 - \frac{T}{C_3})^{C_4})}}$$

untuk water mengunakan persamaan:

$$\rho = C_1 + C_2 T + C_3 T^2 + C_4 T^3$$

Dari J.A.Dean didapatkan ρ S2Cl2 = 0.68880 g/cm^3 = 688.80 kg/m^3

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
H_2O	155.01835	0.0062	956.8928	5.9701
CCl4	273.88325	0.0110	246.1238	2.7130
S2Cl2	24417.782	0.9827	688.8000	676.9100
Total	24846.683	1.0000	1891.8166	685.5930

$$\rho \text{ campuran} = \frac{685.5930}{1.0000} = 685.5930 \text{ kg/m}^3 = 42.78101 \text{ lb/ft}^3$$

Dari Perry 8th Edition tabel 2-313 Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
H_2O	-52.8430	3703.6	5.866	-5.88E-29	10
CCl4	-8.0738	1121.1	-0.4726		

dimana μ dalam Pa.s $\mu = \exp(C1 + C2/T + C3\ln T + C4T^{C5}$

Dari J.A.Dean didapatkan μ S2Cl2 = 1.90800 cP = 0.0019 Pa.s

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
H_2O	155.01835	0.0245549	0.00021	0.00014111	3.465E-06
CCl4	273.88325	0.0433831	0.00030	0.00020159	8.746E-06
S2Cl2	24417.782	3.8677766	0.00191	0.00128212	0.0049589
Total	24846.683	3.9357	0.00242	0.0016	0.004971

μ campuran = $\frac{\sum xi.\mu i}{\sum xi}$

= $\frac{0.004971}{3.9357}$ = 0.001263 lb/ft.s = 4.547115 lb/ft.jam

Rate bahan masuk (m) = 24846.683 kg/jam

= 54776.998 lb/jam

PERHITUNGAN :

A. Menghitung Rate Volumetrik (Q)

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

= $\frac{54776.998}{42.7810}$

= 1280.4046 ft^3/jam

= 0.3557 ft^3/s

= 159.6362 gpm

$Di_{optimum}$ = $3{,}9\ Q^{0{,}45} \times \rho^{0{,}13}$ (Pers.15 "Petters&Timmerhaus",hal 496)

= $3.9 \times 0.3557^{0{,}45} \times 42.7810^{0{,}13}$

= 3.9911 ≈ 3.5 in

= 0.2917 ft

Untuk pipa ukuran 3.5 in sch 40

Dari Brownell and Young, App.K-2 Hal.387 didapatkan:

OD = 4.000 in = 0.3333 ft

ID = 3.548 in = 0.2957 ft

A = 0.06870 ft^2

B. Menentukan Kecepatan Aliran Fluida (v)

Kecepatan aliran fluida = $\frac{Q}{A}$

= $\frac{1280.4046}{0.06870}$

= 18637.6221 ft/jam

= 5.1771 ft/s

C. Menentukan Bilangan Reynold

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

$= \frac{0.29567 \times 5.1771 \times 42.7810}{0.001263}$

= 51845.123 ≥ 4000 (aliran turbulen)

DariGeankoplis, Fig. 2.10-3 Hal. 88 didapatkan:

Equivalent rougness(ε) = 4.6E-05 m

Relative rougness $\frac{\varepsilon}{D}$ = 0.0005

Faktor friksi (f) = 0.001

α = 1

D. Menentukan Panjang Pipa

Asumsi :

- Panjang pipa lurus = 150 ft
- elbow 90^o = 3 buah
  - Le/D = 35 (Geankoplis,Tabel 2-10.1 Hal 93)
  - L elbow = 35 ID
  - = 35 × 3 × 0.33333 ft
  - = 35.000 ft
- Globe valve = 1 buah
  - Le/D = 300 (Geankoplis,Tabel 2-10.1 Hal 93)
  - L elbow = 300 ID
  - = 300 × 1 × 0.33333 ft
  - = 100.000 ft

Panjang pipa total (L) = Pipa lurus + elbow 90^o + globe valve

= 150 + 35.000 + 100.000

= 285.000 ft

= 3420 in

E. Menentukan friksion Loss

1. Friksi pada pipa lurus

$F_f = 4f \frac{\Delta L}{D} \times \frac{v^2}{2g_c}$ (Geankoplis, Pers.2-10.6 Hal 86)

$= 4 \times 0.0010 \frac{285.0000}{0.2956667} \times \frac{5.1771^2}{2 \times 32.2}$

= 1.6060 lbf.ft/lbm

2. Kontraksi pada keluaran tangki

$$hc = Kc \frac{v^2}{2g_c}$$ (Geankoplis, Pers.2-10.16 Hal 93)

$$= 0.55 \frac{5.1771^2}{2 \times 32.174}$$

$= 0.2291$ lbf.ft/lbm

3. Elbow 90^o, 2 buah

$K_f = 0.75$ (Geankoplis, Tabel 2.10-1 Hal. 93

$$hf = 2Kf \frac{v^2}{2g_c}$$ (Geankoplis, Pers.2-10.17 Hal 94)

$$= 2 \times 0.75 \frac{5.1771^2}{2 \times 32.174}$$

$= 0.6248$ lbf.ft/lbm

Total friksi (∑F) = 1.6060 + 0.2291 + 0.624787
= 2.4599 lbf.ft/lbm

F. Menentukan Kesetimbangan Mekanik

Direncanakan:

ΔZ = 30 ft

ΔP = 0 lb/ft^2

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

v_2 = 5.177 ft/s

α = 1 (aliran turbulen)

Sehingga Mechanical energy balance :

$$\frac{V_2 - V_1}{2.\alpha.gc} + \Delta Z \frac{g}{gc} + \frac{\Delta P}{\rho} + \sum F = -Ws$$

$$\frac{5.1771 - 0}{2 \times 1 \times 32.17} + 30 \frac{32.17}{32.17} + 2.4599 = -Ws$$

-Ws = 32.5403 lbf.ft/lbm

Dengan: Capacity = 159.636 gal/menit
μ campuran = 2.4180 Centipoise

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

Efisiensi pompa (η) = 90%
Ws = - η Wp
32.5403 = - 90% Wp
Wp = 36.1559 ft.lbf/lbm

mass flow rate (m) = Q x ρ

$= 1280.4046 \times 42.7810$

$= 54776.998$ lbm/jam

$= 15.2158$ lbm/s

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

$$WHp = 36.1559 \times 15.2158 \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

$WHp = 1.0003$ hp

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

$$= \frac{1.0003}{90\%}$$

$= 1.1114$ Hp

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

Efisiensi motor = 90%

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

$$= \frac{1.1114}{90\%}$$

$= 1.2349$ Hp $\approx$ 1 Hp

Spesifikasi Pompa Sentrifugal

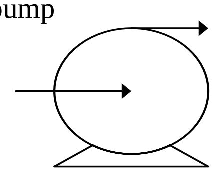
Fungsi	:	Untuk mengalirkan bottom product D-130 menuju reboiler (E-138)
Kode alat	:	L-137
Tipe	:	Centrifugal pump
Kapasitas	:	159.636 gpm
Suhu operasi	:	408.15 K
Tekanan operasi	:	1 atm
Efisiensi Pompa	:	90%
ΔP	:	0 lb/ft^2
Bahan Konstruksi	:	Carbon steel
Daya	:	1 Hp
Dimensi		

NPS	:	3.5	in	OD	:	4.000	in	A	:	0.06870 ft^2
Sch	:	40		ID	:	3.548	in			

16. Pompa sentrifugal (L-134e)

Fungsi : Untuk mengalirkan bottom product kolom distilasi (D-130) menuju pengemasan produk

Tipe : Centrifugal pump



Direncanakan :

Bahan konstruksi = Carbon steel

Jumlah = 1 buah

Kondisi operasi :

Suhu (T) = 135 ^oC = 408.15 K

Tekanan (P) = 1 atm = 14.7 psia = 0 psig

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06
CCl4	154	0.99835	0.27400	556.3500	0.28700

dimana, ρ dalam mol/m^3

$$\rho = \frac{C_1}{C_2^{(1 + (1 - \frac{T}{C_3})^{C_4}}}$$

untuk water mengunakan persamaan:

$$\rho = C_1 + C_2 T + C_3 T^2 + C_4 T^3$$

Dari J.A.Dean didapatkan ρ S2Cl2 = 0.68880 g/cm^3 = 688.80 kg/m^3

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
H_2O	39.387599	0.0062	956.8928	5.9701
CCl4	69.589205	0.0110	246.1238	2.7130
S2Cl2	6204.1545	0.9827	688.8000	676.9100
Total	6313.1313	1.0000	1891.8166	685.5930

ρ campuran = $\frac{685.5930}{1.0000}$ = 685.5930 kg/m^3 = 42.78101 lb/ft^3

Dari Perry 8th Edition tabel 2-313 Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
H_2O	-52.8430	3703.6	5.866	-5.88E-29	10
CCl4	-8.0738	1121.1	-0.4726		

dimana μ dalam Pa.s $\mu = \exp(C1 + C2/T + C3 \ln T + C4 T^{C5}$

Dari J.A.Dean didapatkan μ S2Cl2 = 1.90800 cP = 0.0019 Pa.s

Komponen	Massa	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi

Komponen	(Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
H_2O	39.387599	0.006239	0.00020	0.00013507	8.427E-07
CCl4	69.589205	0.0110229	0.00028	0.00019054	2.1E-06
S2Cl2	6204.1545	0.9827381	0.00191	0.00128212	0.00126
Total	6313.1313	1.0000	0.00239	0.0016	0.001263

$$\mu \text{ campuran} = \frac{\sum xi.\mu i}{\sum xi}$$

$$= \frac{0.001263}{1.0000} = 0.001263 \text{ lb/ft.s} = 4.546541 \text{ lb/ft.jam}$$

Rate bahan masuk (m) = 6313.1313 kg/jam
= 13917.929 lb/jam

PERHITUNGAN :

A. Menghitung Rate Volumetrik (Q)

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

$$= \frac{13917.929}{42.7810}$$

= 325.3296 ft^3/jam

= 0.0904 ft^3/s

= 40.5609 gpm

$Di_{optimum}$ = $3{,}9\ Q^{0,45} \times \rho^{0,13}$ (Pers.15 "Petters&Timmerhaus",hal 496)

= $3.9 \times 0.0904^{0,45} \times 42.7810^{0,13}$

= 2.1545 ≈ 2 in

= 0.1667 ft

Untuk pipa ukuran 2 in sch 40

Dari Brownell and Young, App.K-2 Hal.387 didapatkan:

OD = 2.375 in = 0.1979 ft

ID = 2.067 in = 0.1723 ft

A = 0.02330 ft^2

B. Menentukan Kecepatan Aliran Fluida (v)

$$\text{Kecepatan aliran fluic} = \frac{Q}{A}$$

$$= \frac{325.3296}{0.02330}$$

$= 13962.6456$ ft/jam
$= 3.8785$ ft/s

C. Menentukan Bilangan Reynold

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

$= \frac{0.17225 \times 3.8785 \times 42.7810}{0.001263}$

$= 22630.64 \geq 4000$ (aliran turbulen)

DariGeankoplis, Fig. 2.10-3 Hal. 88 didapatkan:

Equivalent rougness(ε) = 4.6E-05 m

Relative rougness $\frac{\varepsilon}{D}$ = 0.0009

Faktor friksi (f) = 0.001

α = 1

D. Menentukan Panjang Pipa

Asumsi :

- Panjang pipa lurus = 150 ft
- elbow 90^o = 3 buah
  Le/D = 35 (Geankoplis,Tabel 2-10.1 Hal 93)
  L elbow = 35 ID
  $= 35 \times 3 \times 0.19792$ ft
  $= 20.781$ ft
- Globe valve = 1 buah
  Le/D = 300 (Geankoplis,Tabel 2-10.1 Hal 93)
  L elbow = 300 ID
  $= 300 \times 1 \times 0.19792$ ft
  $= 59.375$ ft

Panjang pipa total (L) = Pipa lurus + elbow 90^o + globe valve
$= 150 + 20.781 + 59.375$
$= 230.156$ ft
$= 2762$ in

E. Menentukan friksion Loss

1. Friksi pada pipa lurus

$F_f = 4f \frac{\Delta L}{D} \times \frac{v^2}{2g_c}$ (Geankoplis, Pers.2-10.6 Hal 86)

$= 4 \times 0.0010 \frac{230.1563}{0.17225} \times \frac{3.8785^2}{2 \times 32.2}$

$= 1.2495$ lbf.ft/lbm

2. Kontraksi pada keluaran tangki

$hc = Kc \frac{v^2}{}$ (Geankoplis, Pers.2-10.16 Hal 93)

hc = Kc $\frac{v^2}{2g_c}$

$= 0.55 \frac{3.8785^2}{2 \times 32.174}$

= 0.1286 lbf.ft/lbm

3. Elbow 90^o, 2 buah

K_f = 0.75 (Geankoplis, Tabel 2.10-1 Hal. 93

hf = $2Kf \frac{v^2}{2g_c}$ (Geankoplis, Pers.2-10.17 Hal 94)

$= 2 \times 0.75 \frac{3.8785^2}{2 \times 32.174}$

= 0.3507 lbf.ft/lbm

Total friksi (∑F) = 1.2495 + 0.1286 + 0.35066

= 1.7287 lbf.ft/lbm

F. Menentukan Kesetimbangan Mekanik

Direncanakan:

ΔZ = 30 ft

ΔP = 0 lb/ft^2

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

v_2 = 3.879 ft/s

α = 1 (aliran turbulen)

Sehingga Mechanical energy balance :

$$\frac{V_2 - V_1}{2.\alpha.gc} + \Delta Z \frac{g}{gc} + \frac{\Delta P}{\rho} + \sum F = -Ws$$

$$\frac{3.8785 - 0}{2 \times 1 \times 32.17} + 30 \frac{32.17}{32.17} + 1.7287 = -Ws$$

-Ws = 31.7890 lbf.ft/s

Dengan: Capacity = 40.5609 gal/menit

μ campuran = 2.3926 Centipoise

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

Efisiensi pompa (η) = 90%

Ws = - η Wp

31.7890 = - 90% Wp

Wp = 35.3211 ft.lbf/s

mass flow rate (m) = Q x ρ

= 325.3296 × 42.7810

= 13917.929 lbm/jam

$$= 3.8661 \text{ lbm/s}$$

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

$$WHp = 35.3211 \times 3.8661 \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

$$WHp = 0.2483 \text{ hp}$$

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

$$= \frac{0.2483}{90\%}$$

$$= 0.2759 \text{ Hp}$$

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

Efisiensi motor = 90%

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

$$= \frac{0.2759}{90\%}$$

$$= 0.3065 \text{ Hp} \approx 1 \text{ Hp}$$

Spesifikasi Pompa Sentrifugal

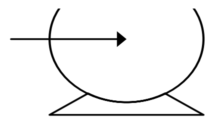
Fungsi	:	Untuk mengalirkan bottom product D-130 menuju pengemasan produk (P-137)
Kode alat	:	L-134
Tipe	:	Centrifugal pump
Kapasitas	:	40.5609 gpm
Suhu operasi	:	408.15 K
Tekanan operasi	:	1 atm
Efisiensi Pompa	:	90%
ΔP	:	0 lb/ft^2
Bahan Konstruksi	:	Carbon steel
Daya	:	1 Hp
Dimensi		

NPS	:	2 in	OD	:	2.375 in	A	:	0.02330 ft^2
Sch	:	40	ID	:	2.067 in			

17 Pompa sentrifugal (L-134C)

Fungsi : Untuk mengalirkan menuju cooler (E-135b)

Tipe : Centrifugal pump



Direncanakan :

Bahan konstruksi = Carbon steel

Jumlah = 1 buah

Kondisi operasi :

Suhu (T) = 135 ^oC = 408.15 K

Tekanan (P) = 1 atm = 14.7 psia = 0 psig

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06
CCl4	154	0.99835	0.27400	556.3500	0.28700

dimana, ρ dalam mol/m^3

$$\rho = \frac{C_1}{C_2^{(1+(1-\frac{T}{C_3})^{C_4}}}$$

untuk water mengunakan persamaan:

$$\rho = C_1 + C_2 T + C_3 T^2 + C_4 T^3$$

Dari J.A.Dean didapatkan ρ S2Cl2 = 0.68880 g/cm^3 = 688.80 kg/m^3

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
H_2O	155.01835	0.0062	956.8928	5.9701
CCl4	273.88325	0.0110	246.1238	2.7130
S2Cl2	24417.782	0.9827	688.8000	676.9100
Total	24846.683	1.0000	1891.8166	685.5930

$$\rho \text{ campuran} = \frac{685.5930}{1.0000} = 685.5930 \text{ kg/m}^3 = 42.78101 \text{ lb/ft}^3$$

Dari Perry 8th Edition tabel 2-313 Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
H_2O	-52.8430	3703.6	5.866	-5.88E-29	10
CCl4	-8.0738	1121.1	-0.4726		

dimana μ dalam Pa.s $\mu = \exp(C1 + C2/T + C3\ln T + C4T^{C5}$

Dari J.A.Dean didapatkan μ S2Cl2 = 1.90800 cP = 0.0019 Pa.s

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
H_2O	155.01835	0.0245549	0.00021	0.00014111	3.465E-06
CCl4	273.88325	0.0433831	0.00030	0.00020159	8.746E-06
S2Cl2	24417.782	3.8677766	0.00191	0.00128212	0.0049589
Total	24846.683	3.9357	0.00242	0.0016	0.004971

μ campuran = $\frac{\sum xi.\mu i}{\sum xi}$

= $\frac{0.004971}{3.9357}$ = 0.001263 lb/ft.s = 4.547115 lb/ft.jam

Rate bahan masuk (m) = 24846.683 kg/jam
= 54776.998 lb/jam

PERHITUNGAN :

A. Menghitung Rate Volumetrik (Q)

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

= $\frac{54776.998}{42.7810}$

= 1280.4046 ft^3/jam
= 0.3557 ft^3/s
= 159.6362 gpm

Di $_{optimum}$ = $3{,}9\ Q^{0{,}45} \times \rho^{0{,}13}$ (Pers.15 "Petters&Timmerhaus",hal 496)
= $3.9 \times 0.3557^{0{,}45} \times 42.7810^{0{,}13}$
= 3.9911 ≈ 3.5 in
= 0.2917 ft

Untuk pipa ukuran 3.5 in sch 40

Dari Brownell and Young, App.K-2 Hal.387 didapatkan:

OD = 4.000 in = 0.3333 ft
ID = 3.548 in = 0.2957 ft
A = 0.06870 ft^2

B. Menentukan Kecepatan Aliran Fluida (v)

Kecepatan aliran fluida = $\frac{Q}{A}$

= $\frac{1280.4046}{0.06870}$

= 18637.6221 ft/jam
= 5.1771 ft/s

C. Menentukan Bilangan Reynold

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

$= \dfrac{0.29567 \times 5.1771 \times 42.7810}{0.001263}$

$= 51845.123 \geq 4000$ (aliran turbulen)

DariGeankoplis, Fig. 2.10-3 Hal. 88 didapatkan:

Equivalent rougness(ε) = 4.6E-05 m

Relative rougness $\dfrac{\varepsilon}{D}$ = 0.0005

Faktor friksi (f) = 0.001

α = 1

D. Menentukan Panjang Pipa

Asumsi :

- Panjang pipa lurus = 150 ft
- elbow 90^o = 3 buah

  Le/D = 35 (Geankoplis,Tabel 2-10.1 Hal 93)

  L elbow = 35 ID

  = 35 × 3 × 0.33333 ft

  = 35.000 ft
- Globe valve = 1 buah

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

  L elbow = 300 ID

  = 300 × 1 × 0.33333 ft

  = 100.000 ft

Panjang pipa total (L) = Pipa lurus + elbow 90^o + globe valve

= 150 + 35.000 + 100.000

= 285.000 ft

= 3420 in

E. Menentukan friksion Loss

1. Friksi pada pipa lurus

$F_f = 4f \dfrac{\Delta L}{D} \times \dfrac{v^2}{2g_c}$ (Geankoplis, Pers.2-10.6 Hal 86)

$= 4 \times 0.0010 \; \dfrac{285.0000}{0.2956667} \times \dfrac{5.1771^2}{2 \times 32.2}$

$= 1.6060$ lbf.ft/lbm

2. Kontraksi pada keluaran tangki

$$hc = Kc \frac{v^2}{2g_c}$$ (Geankoplis, Pers.2-10.16 Hal 93)

$$= 0.55 \frac{5.1771^2}{2 \times 32.174}$$

$$= 0.2291 \text{ lbf.ft/lbm}$$

3. Elbow 90^o, 2 buah

K_f = 0.75 (Geankoplis, Tabel 2.10-1 Hal. 93

$$hf = 2Kf \frac{v^2}{2g_c}$$ (Geankoplis, Pers.2-10.17 Hal 94)

$$= 2 \times 0.75 \frac{5.1771^2}{2 \times 32.174}$$

$$= 0.6248 \text{ lbf.ft/lbm}$$

Total friksi (∑F) = 1.6060 + 0.2291 + 0.624787
= 2.4599 lbf.ft/lbm

F. Menentukan Kesetimbangan Mekanik

Direncanakan:

ΔZ = 30 ft

ΔP = 0 lb/ft^2

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

v_2 = 5.177 ft/s

α = 1 (aliran turbulen)

Sehingga Mechanical energy balance :

$$\frac{V_2 - V_1}{2.\alpha.gc} + \Delta Z \frac{g}{gc} + \frac{\Delta P}{\rho} + \sum F = - Ws$$

$$\frac{5.1771 - 0}{2 \times 1 \times 32.17} + 30 \frac{32.17}{32.17} + 2.4599 = - Ws$$

-Ws = 32.5403 lbf.ft/lbm

Dengan: Capacity = 159.636 gal/menit
μ campuran = 2.4180 Centipoise

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

Efisiensi pompa (η) = 90%

Ws = - η Wp

32.5403 = - 90% Wp

Wp = 36.1559 ft.lbf/lbm

mass flow rate (m) = Q x ρ

$= 1280.4046 \times 42.7810$

$= 54776.998$ lbm/jam

$= 15.2158$ lbm/s

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

$$WHp = 36.1559 \times 15.2158 \times \frac{1 \text{ hp}}{550 \text{ ft.lbf/s}}$$

$WHp = 1.0003$ hp

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

$$= \frac{1.0003}{90\%}$$

$= 1.1114$ Hp

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

Efisiensi motor = 90%

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

$$= \frac{1.1114}{90\%}$$

$= 1.2349$ Hp ≈ 1 Hp

Spesifikasi Pompa Sentrifugal

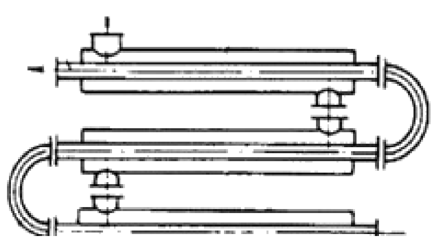
Fungsi	: Untuk mengalirkan ke cooler (E-135b)
Kode alat	: L-134
Tipe	: Centrifugal pump
Kapasitas	: 159.636 gpm
Suhu operasi	: 408.15 K
Tekanan operasi	: 1 atm
Efisiensi Pompa	: 90%
ΔP	: 0 lb/ft^2
Bahan Konstruksi	: Carbon steel
Daya	: 1 Hp
Dimensi	

NPS	:	3.5 in	OD	:	4.000 in	A	:	0.06870 ft^2
Sch	:	40	ID	:	3.548 in			

23. Cooler (E-135 b)

Fungsi : Untuk mendinginkan bottom product dari D-130 ke 30 oC

Tipe : Double Pipe Heat Exchanger



Direncanakan :

faktor kekotoran gabungan minimum (Rd)	=	0.001	jam.ft^{2}.^{0}F/Btu
Δp maksimum aliran	=	10	psi
Δp maksimum steam	=	2.5	psi

Dasar perencangan :

Dari Appendix B didapatkan data sebagai berikut:

- Massa bahan masuk = 6,313.131 kg/jam
  = 13,917.929 Ib/jam
- Suhu bahan masuk (t_1) = 135 °C = 275.00 °F
- Suhu bahan keluar (t_2) = 30 °C = 86.00 °F
- Kebutuhan pendingin (m) = 482.7528 kg/jam
  = 1,064.2769 Ib/jam
- Panas yang dibawa coolant = 89,590.2327 kkal/jam
  = 355,291.2147 btu/jam
- water masuk pada suhu (T_1) = 27 °C = 81 °F = 300.15 K
- water keluar pada suhu (T_2) = 50 °C = 122 °F = 323.15 K

Perhitungan :

1. Menghitung Δt

$\Delta t_1 = t_1 - T_2 = 275 - 122 = 153\ ^0F$

$\Delta t_2 = t2 - T1 = 86 - 81 = 5.4\ ^0F$

$$\Delta T_{LMTD} = \frac{\Delta t_1 - \Delta t_2}{\ln \frac{\Delta t1}{\Delta t2}} = \frac{153 - 5.4}{\ln \frac{153}{5.4}} = 44.138\ ^0F$$

2. Menghitung suhu caloric (Tc dan tc)

Tc = $(T_1 + T_2) /$ = 101 ^{o}F = 39 ^{0}C = 311.65 K

tc = $(t_1 + t_2) / 2$ = 181 ^{o}F = 82.5 ^{0}C = 355.65 K

Viskositas aliran pada anulus (bahan):

Dari Perry 8th Edition tabel 2-313 Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
H_2O	-52.8430	3703.6	5.866	-5.88E-29	10

CCl4	-8.0738	1121.1	-0.4726		

dimana μ dalam Pa.s $\mu = \exp(C1 + C2/T + C3\ln T + C4T^{C5}$

Dari J.A.Dean didapatkan μ S2Cl2 = 1.90800 cP = 0.0019 Pa.s

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
H_2O	39.387599	0.0006239	0.00034	0.00022847	1.425E-07
CCl4	69.589205	0.0110229	0.00045	0.00030239	3.333E-06
S2Cl2	6204.1545	0.9827381	0.00191	0.00128212	0.00126
Total	6313.1313	1.0	0.00270	0.0018	0.001263

$$\mu \text{ campuran} = \frac{\sum xi.\mu i}{\sum xi}$$

$$= \frac{0.001263}{0.9944} = 0.001271 \text{ lb/ft.s} = 4.574143 \text{ lb/ft.jam}$$

Viskositas aliran pada pipe (cooling water):

Dari Perry 8th Edition tabel 2-313Hal. 2-427 didapatkan tabel berikut:

Komponen	C1	C2	C3	C4	C5
H_2O	-52.84300	3703.6000	5.8660	-5.9.E-29	10

dimana μ dalam Pa.s

$$\mu = \exp(C1 + C2/T + C3\ln T + C4T^{C5}$$

Komponen	Massa (Kg/jam)	xi (massa)	μ (Pa.s)	μ (lb/ft.s)	xi.μi
H_2O	482.7528	1.0000	0.00069	0.000464	0.000464

Densitas aliran pada anulus (bahan):

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06
CCl4	154	0.99835	0.27400	556.3500	0.28700

dimana, ρ dalam mol/m^3

$$\rho = \frac{C_1}{C_2^{\left(1 + \left(1 - \frac{T}{C_3}\right)^{C_4}\right)}}$$

untuk water mengunakan persamaan:

$$\rho = C_1 + C_2T + C_3T^2 + C_4T^3$$

Dari J.A.Dean didapatkan ρ S2Cl2 = 0.68880 g/cm^3 = 688.80 kg/m^3

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
H_2O	39.387599	0.0062	976.1747	6.0523
CCl4	69.589205	0.0110	254.9032	2.8039
S2Cl2	6204.1545	0.9827	688.8000	676.8838
Total	6313.1313	1.000	1919.8779	685.7400

ρ campuran $= \dfrac{685.7400}{0.9999} = 685.8086$ kg/m^3 $= 42.79445$ lb/ft^3

Trial ukuran DPHE
Dicoba ukuran DPHE : 4x 3" IPS sch.40 dengan aliran cooling water di bagian
Dari Kern, tabel 6.2 hal.110 didapatkan :

a_{an} = 3.14 in^2 = 0.0218 ft^2
a_p = 7.38 in^2 = 0.0513 ft^2
de = 1.14 in = 0.0950 ft
de' = 0.53 in = 0.0442 ft

Dari Kern, tabel 11 hal.844 didapatkan :

dop = 3.5 in = 0.0243 ft
dip = 3.07 in = 0.2557 ft
a'' = 0.92 ft^2/ft

Evaluasi Perpindahan Panas

Cold fluid: pipe, cooling water

1. Menghitung NRe

$G_p = \dfrac{M}{a_p}$

$= \dfrac{1064.2769 \text{ lb/jam}}{0.0513 \text{ ft}^2}$

= 20766.378 lb/jam.ft^2

pada Tc = 101 ^{o}F
μ = 0.000464 lb/ft.s
= 1.669171 lb/ft.jam
di = 3.07 in
= 0.256 ft

$Nre_p = \dfrac{G_p \times di}{\mu}$

$$\mu = \exp(C1 + C2/T + C3\ln T + C4T^{C5})$$

1.669171

= 3180.7831

2. Velocity

Hot fluid: anulus, residu D-130

1'. Menghitung NRe

$G_{an} = \dfrac{m}{a_{an}}$

$= \dfrac{13917.929 \text{ lb/jam}}{0.0218 \text{ ft}^2}$

= 638274.463 lb/jam.ft^2

pada tc = 181 ^{o}F
μ = 0.001271 lb/ft.s
= 4.57414 lb/ft.jam
de = 1.14 in
= 0.10 ft

$Nre_{an} = \dfrac{G_{an} \text{ x } de}{\mu}$

$= \dfrac{638274.4631 \times 0.10}{4.57414}$

= 13256.2699

2'. Menghitung faktor panas (J_H)

$v = \dfrac{G_p}{3600\rho}$

$= \dfrac{20766.38}{3600 \times 61.916}$

$= 9.3164951$ fps

3. Menghitung harga koefisien film perpindahan panas

Dari Kern, Fig. 25 Hal.835 , didapatkan:

hi = 1600 Btu/jam.ft^{2o}F

faktor koreksi = 1.1

sehingga,

$hio = hi \left(\dfrac{di}{do}\right)$

$= 1760 \left(\dfrac{0.2557}{0.0243}\right)$

= 18513 Btu/jam.ft^{2o}F

Dari Kern, Fig. 24 Hal.834 didapatka

J_H = 39

3'. Menghitung harga koefisien film

Dari Kern, Tabel 4 hal.800 didapatka

k = 0.098718 Btu/jam.ft^2.^{o}F/ft

Dari Kern, Fig.3 hal.805 didapatkan:

Cp = 0.234 Btu/lb.^{o}F

maka,

k (Cp.μ /k)$^{1/3}$ = 0.2186

ho/φs = 89.76

tw = 180.88 ^{o}F

dimana μ Pada suhu tw didapatkan:

μw = 0.58 lb/ft.jam

μ /μw = 7.885

Dari Kern, Fig. 24 Hal.834 didapatkan:

φs = 1.335

sehingga,

ho = 119.846 Btu/jam.ft^{2o}F

Clean overall coefficient Uc :

$U_c = \dfrac{hio \cdot ho}{hio + ho} = \dfrac{18513 \times 119.846}{18513 + 119.846} = 239.692$ Btu/ft^2.jam^{0}F

Dirt factor (faktor kekotoran) pipa terpakai

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

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

$\dfrac{1}{U_D} = 0.001 + \dfrac{1}{239.692}$

$\dfrac{1}{U_D} = 0.005$

U_D = 193.35 jam.ft^2.°F/Btu

$A = \dfrac{Q}{UD \cdot \Delta t} = \dfrac{355291.2147}{193.35 \times 44.138} = 41.632$ ft^2

$L = \dfrac{A}{a''} = \dfrac{41.632}{0.9170} = 45.400$ ft

Mencari panjang ekonomis dengan mencari over design yang terkecil dari pipa standar.

Panjang pipa (ft)	Hairpin (n)	pembulatan Hairpin	L_{baru}	A baru	UD baru	Rd baru	Rd over des (%)
12	1.8941	2	48	44.0160	211.875	0.002	0.070
16	1.4205	2	64	58.6880	158.906	0.003	2.271
20	1.1364	2	80	73.3600	127.125	0.005	3.845

Jadi, diambi over desain yang terkecil = 0.070 %

L = 80 ft

n = 2 buah

Evaluasi ΔP

Cold fluid: pipe, cooling water

1. Pada Nre p = 3180.78

f = ##### + $\frac{0.264}{(\text{Nre p})^{0,42}}$

= ##### + $\frac{0.264}{3180.78^{0,42}}$

= 0.0124

Dari Geankoplis, tabel.A-23 Hal.855 didapatkan:

ρ = 992.25 kg/m^3

= 61.916 lb/ft^3

$\Delta Fp = \frac{4.f.Gp^2.L}{2.g.\rho^2.di}$

$= \frac{4 \times \#\#\#\#\# \times 20766.38^2 \times 80}{2 \times 4.18 \times 61.92^2 \times 0.256}$

= 0.0589 ft

$\Delta Pp = \frac{0.0589 \times 61.916}{144}$

= 0.0253 psi < 2.5 psi

Hot fluid: anulus, residu D-130

1'. de' = 0.0442 ft

$Nre_{an} = \frac{G_{an} \times de'}{\mu}$

$= \frac{638274.4631 \times 0.044}{4.57414}$

= 6163.0027

f = 0.0035 + $\frac{0.264}{(\text{Nre an})^{0,42}}$

= 0.0035 + $\frac{0.264}{6163.00^{0,42}}$

= 0.0103

ρ = 42.7945 lb/ft^3

karena panjang pipa,

$\Delta Fa = \frac{4.f.Ga^2.L}{2.g.\rho^2.de'}$

$= \frac{4 \times 0.0103 \times 638274.5^2 \times}{2 \times 4.18 \times 42.79^2 \times 0.0}$

= 19.77879 ft

karena tube passes,

$v = \frac{Ga}{3600\rho}$

$= \frac{638274.5}{3600 \times 42.7945}$

= 4.143024 fps

$Fl = n\left(\frac{v^2}{2gc}\right)$

= 2 (4.143)

$$\left(2 \times 32.2 \right)$$

$$= 0.128665$$

$$\Delta Pa = \frac{\left(19.779 + 0.129 \right) \times 42.79}{144}$$

$$= 5.916172 \text{ psi} < 10.0 \text{ psi}$$

desain memenuhi

Spesifikasi Cooler

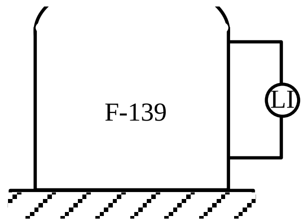
Fungsi	:	Untuk mendinginkan bottom product dari D-130 ke 30^oC						
Kode alat	:	E-135 b						
Tipe	:	Double pipe Heat Exchanger 4 x 3" sch.40						
Bahan Konstruksi	:	Carbon steel SA-135 Grade B						
Media pendingin	:	Cooling water 27 ^oC ,						
Kapasitas	:	6,313.1313 kg/jam = 13,917.929 lb/jam						
Rate pendingin	:	482.7528 kg/jam = 1,064.2769 lb/jam						
Dimensi		*Pipe side* , cooling water			*Anullus side* , residu D-130			
		do	=	3.5 in	a_{an}	=	0.0218	ft
		L_{pipe}	=	20 ft	de	=	0.0950	ft
		ap	=	7.38 in^2	de'	=	0.0442	ft
		Hairpin	=	2 buah	L	=	80	ft
		ΔPp	=	0.0253 psi	ΔPan	=	5.9162	psi

$$\left(\frac{v^2}{2gc}\right)$$

24. Storage Tank Sulfur Monochloride (F-139)

Fungsi : Untuk menampung by-product sulfur monochloride

Tipe : Tangki bentuk silinder tegak dengan tutup atas berbentuk standard dished dan dasar berbentuk datar (flat bottom)



Direncanakan :

Bahan konstruksi = Carbon steels SA-135 Grade B
Allowable stress (*f*) = 12750 psi
Tipe pengelasan = Double welded but joint (E = 0.8)
Faktor korosi (C) = 1/16 in
Waktu tinggal = 7 hari
Volume ruang kosong = 20% Volume total
Jumlah tangki = 2 buah

Kondisi operasi :

Suhu operasi = 27 ^oC = 300.15 K
Tekanan operasi = 1 atm = 14.7 psia = 0 psig

Dari Perry 8th Edition tabel 2-32 Hal. 2-98 didapatkan tabel berikut:

Komponen	berat molekul	C1	C2	C3	C4
H_2O	18	-13.85100	0.64038	-0.0019	1.8.E-06
CCl4	154	0.99835	0.27400	556.3500	0.28700

dimana, ρ dalam mol/m^3

$$\rho = \frac{C_1}{C_2^{\left(1+\left(1-\frac{T}{C_3}\right)^{C_4}\right)}}$$

untuk water mengunakan persamaan:

$$\rho = C_1 + C_2T + C_3T^2 + C_4T^3$$

Dari J.A.Dean didapatkan ρ S2Cl2 = 0.68880 g/cm^3 = 688.80 kg/m^3

Komponen	Massa (Kg/jam)	xi (massa)	ρ (kg/m^3)	xi.ρi
H_2O	39.387599	0.0062	999.5509	6.2362
CCl4	69.589205	0.0110	264.5320	2.9159
S2Cl2	6204.1545	0.9827	688.8000	676.9100
Total	6313.1313	1.0000	1952.8829	686.0621

$$\rho \text{ campuran} = \frac{686.0621}{1.0000} = 686.0621 \text{ kg/m}^3 = 42.81027 \text{ lb/ft}^3$$

Rate bahan masuk (m) = 6313.1313 kg/jam
= 13917.929 lb/jam

PERHITUNGAN

A. Menghitung Volume Tangki

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

$= \frac{6313.1313 \text{ kg/jam}}{686.0621 \text{ kg/m}^3} \times \frac{24 \text{ jam}}{1 \text{ hari}} \times 7 \text{ hari}$

$= 1545.933 \text{ m}^3$

Jumlah produk sulfur monochloride yang harus disimpan dalam 7 hari sebanya
1545.933 m^3 yang disimpan didalai 2 buah tangki storage dimana jika disimpan dalam 1 buah tangki akan membutuhkan volume yang terlalu besar. sehingga,

Volume $= \frac{1545.9330}{2} = 772.966516 \text{ m}^3$

Volume tangki $= \frac{772.9665}{0.8} = 966.208146 \text{ m}^3$

B. Menentukan Dimensi tangki

Asumsi Ls = 1.5 di

Volume tanki = Volume silinder + Tutup atas

$966.2081 = \frac{\pi}{4} di^2 Ls + 0{,}0847\ di^3$

$966.2081 = \frac{\pi}{4} di^2 \times 1{,}5di + 0{,}0847di^3$

$966.2081 = 1.2649\ di^3$

$di^3 = 763.8613$

di = 9.1412 m = 359.8913 in = 29.9906 ft

C. Menghitung Tinggi Liquida

Tinggi liquida (HL) $= \frac{\text{Volume liquida}}{\frac{1}{4}\pi \times di^2}$

$= \frac{772.9665}{\frac{1}{4} \times 3.14 \times 9.1412^2}$

= 11.7837 m = 463.9251 in = 38.6599 ft

D. Menentukan Tekanan Design (Pi)

Tekanan hidrostatik (Ph) = ρ (HL-1)

$$\frac{}{144}$$

$$= \frac{42.8103 \times (38.6599 - 1)}{144}$$

= 11.1961 psia

= 25.8961 psig

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

= 0.0 + 25.8961

= 25.8961 psig

= 1.7855 bar

E. Menghitung Tebal Silinder (ts)

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

$$= \frac{25.8961 \times 359.8913}{2\ (12750 \times 0.8 - 0.6 \times 25.8961\ )} + \frac{1}{1}$$

$$= 0.5197 \times \frac{16}{16}$$

$$ts = \frac{8.3152}{16}\ in \approx \frac{5}{16}\ in$$

do = di + 2(ts)

= 359.8913 + 2(1/3)

= 360.5163 in ≈ 204 in

Berdasarkan "Brownel and Young" tabel 5.7 hal 90, didapatkan :

icr = 12 1/4 in

r = 170 in

di_{baru} = do_{st} - 2ts

= 204 - 2(1/3)

= 203.375 in

= 16.9479 ft

F. Menghitung Tinggi Silinder (Ls)

Tinggi silinder (Ls) = 1.5 × di

= 1.5 × 16.9479 ft

= 25.4219 ft

= 305.063 in

G. Menghitung Dimensi Tutup Atas Dan Tutup Bawah

Bentuk tutup atas adalah standar dish dan tutup bawah adalah flat, sehingga :

r = di_{baru}

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

$$= \frac{0.885 \times 25.8961 \times 203.375}{} + \frac{1}{}$$

$$- \quad 2 \ (\ 12750 \times 0.8 - 0.1 \times 25.8961 \ ) \quad 1$$

$$= 0.2910 \times \frac{16}{16}$$

$$= \frac{4.6566}{16} \approx 4/16 \text{ in}$$

Tinggi Tutup atas = 0.169 × di

= 0.169 × 203.3750 in

= 34.3704 in

H. Menghitung Tinggi Tangki (H)

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

= 305.0625 + 34.3704

= 339.4329 in

= 28.2861 ft

G. Desain Bagian Bawah Tangki

Untuk mempermudah pengelasan dan memperhitungkan terjadinya korosi, mal pada lantai (bottom) dipakai plat dengan tebal minimal 1/2 in. Tegangan yang bekerja pada plat yang digunakan pada lantai harus diperiksa agar diketahui apakah plat yang digunakan telah memenuhi persyaratan atau tidak.

Tegangan yang bekerja pada bottom:

1. Compressive stress yang dihasilkan oleh sulfur monochoride.

$$S_1 = \frac{\sum liquid\ wt}{12\ \pi D_m (t_s - c)}$$ (Brownell,1959. Pers.9-5 Hal 157

Dimana:

ts : tebal shell, in

Dm : diameter shell, ft

liquid wt dalam lb

$$S_1 = \frac{13917.9293}{12 \times 3.14 \times 16.9479 \ (\ 1/3 - 1/16 \ )}$$

S_1 = 87.1781 psi

2. Compressive stress yang dihasilkan oleh berat shell.

$$S_2 = \frac{X\rho_s}{144}$$ (Brownell,1959. Pers.9-3 Hal 156

Dimana:

X : tinggi tangki, ft

ρ_s : densitas material shel 490 lb/ft^3 untuk material steel

$$S_2 = \frac{28.2861 \times 490}{144}$$

= 96.251 psi

Tegangan total yang bekerja pada lantai:

S_t = S_1 + S_2

= 87.1781 + 96.25122

= 183.4293 psi

Batas tegangan lantai yang diizinkan:

$S_t < f.E$

183.4293 < 12750 × 0.8

183.4293 < 10200 sehingga memenuhi

Spesifikasi Storage Tank Sulfur Monochloride

Fungsi	:	Untuk menampung by-product sulfur monochloride
Kode alat	:	F-139
Tipe	:	Silinder tegak dengan tutup bawah berbentuk flat bottom dan tutup bawah berbentuk standard dished
Kapasitas	:	966.20815 m^3
Suhu operasi	:	300.15 K
Tekanan operasi	:	1 atm
Dimensi		
Diameter shell	:	17.0000 ft
Tinggi shell	:	25.4219 ft
Tebal shell	:	1/3 in
Tinggi atap	:	2.8642 ft
Tebal atap	:	1/4 in
Tipe pengelasan	:	Double welded but joint (E = 0.8)
Bahan Konstruksi	:	Carbon steels SA-135 Grade B
Jumlah	:	2 buah

21. Mesin Pengemas (P-138)

Fungsi : Mengemas karbon tetraklorida kedalam tabung silinder

Waktu tinggal : 0.0028 jam

Kapasitas bahan : 15339.2225 kg/jam = 33817 lb/jam

Densitas (liquid) : 42.78 lb/ft^3

Kapasitas mesin : 15339.22 kg/jam x 0.0027789 jam

: 42.63 kg

Spesifikasi :

- Ukuran tabung = 200 L

22. Gudang Produk Utama (F-138)

Fungsi : Untuk menyimpan produk karbon tetraklorida

Tipe : Gudang

Direncanakan :

Waktu Tinggal : 14 Hari = 336 jam

Volume gudang : 80% Storage

Jumlah gudang : 2 Buah
Kapasitas Bahan : 15339.2225 kg/jar = 33,817.2 lb/jam
Kondisi Operasi
Tekanan : 1 atm
Densitas (liquid) : 42.7810 lb/ft^3

Perhitungan :

a. Menghitung Volume Karbon tetraklorida selama

Volume = Massa / densitas

$$= \frac{33,817.2 \text{ lb/jam}}{42.7810 \text{ lb/ft}^3}$$

$= 790.47129 \text{ ft}^3\text{/jam}$

Produk disimpan selama 14 hari

$V_L = 790.47129 \times 14 \text{ hari} \times 24$

$= 265598.35 \text{ ft}^3$

$= 7520.9486 \text{ m}^3$

b. Volume gudang

Produk mengisi gudang s 80% dari volume total

$$\text{Volume total gudang} = \frac{Vl}{80\%}$$

$$= \frac{7520.9486}{80\%}$$

$= 9401.1857 \text{ m}^3$

c. Ukuran gudang

panjang = 2 x lebar gudang
tinggi = 15 m
Maka

$V = P \times L \times T$

$9401.1857 = 2\,L \times L \times 15$

$9401.1857 = 30\ L^2$

$313.37286 = L^2$

$L = 17.702 \text{ m}$

Maka,
Panjang = 35.405 m

Spesifikasi Alat

Nama	:	Gudang Penampung Drum Karbon Tetraklorida
Tipe	:	Bangunan Gedung
Bahan kontruksi	:	Beton
Waktu tinggal	:	14 hari
Panjang	:	35 m
Lebar	:	18 m

Tinggi	:	15	m
Jumlah	:	2	buah