APPENDIX A

PERHITUNGAN NERACA MASSA

Kapasitas produksi : 50.000 kg 80% Acetic Acid

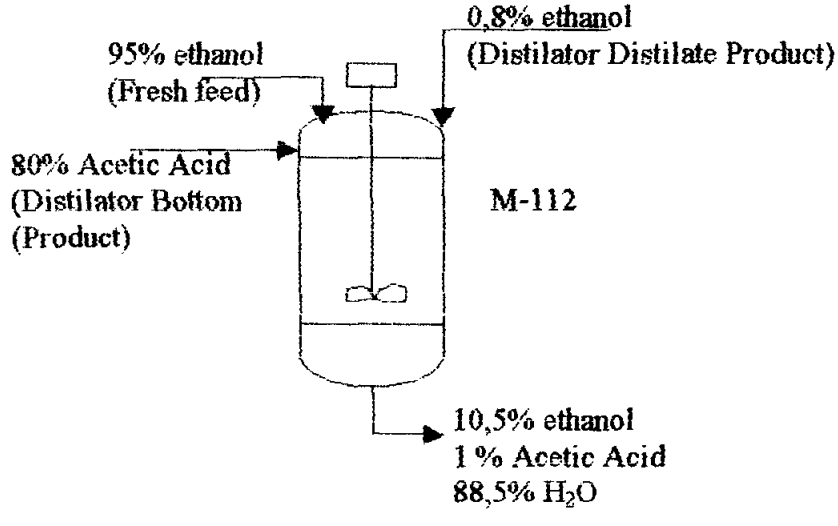
Satuan massa : Kilogram (kg)

Satuan waktu : Hari

I. Raw Material Mixing Tank (M – 112)

1. Fungsi : Untuk mencampur 95 % larutan C_2H_5OH dengan Acetic Acid dan H_2O sehingga membentuk campuran 10,5% C_2H_5OH, 1 % CH_3COOH dan 88,5% H_2O.

2. Gambar :



3. Perhitungan :

Feed untuk Fermentor (disajikan di perhitungan neraca massa Mixing Tank) terdiri dari :

C_2H_5OH	= 33611,760 kg	= 10,5 %	= 0,105
CH_3COOH	= 3201,120 kg	= 1 %	= 0,01
H_2O	= 283299,120 kg	= 88,55	= 0,885
Total	= 320112,000 kg		

Untuk membentuk/membuat komposisi feed seperti tersebut diatas maka dimanfaatkan hasil distillate dari Distilator, dicampur dengan hasil produk bottom Distilator dan 95% C_2H_5OH fresh feed.

Komposisi distillate hasil Distilator adalah sebagai berikut :

C_2H_5OH	= 2405,079 kg = (2405,079 / 287553,401)	= 0,00836393978	
H_2O	= 285148,322 kg = (285148,322/287553,401)	= 0,99163606022	
Total	= 287553,401 kg	Total	= 1,000

Komposisi bottom hasil Distilator adalah sebagai berikut :

CH_3COOH	= 43201,120 kg = (43201,120/54001,400)	= 0,80	
H_2O	= 10260,266 kg = (10260,266/54001,400)	= 0,19	
C_2H_5OH	= 540,014 kg = (540,014/54001,400)	= 0,01	
Total	= 54001,400 kg	Total	= 1,000

Komposisi fresh feed 95% C_2H_5OH

C_2H_5OH	= 0,95
H_2O	= 0,05
Total	= 1,000

Dicari berapa massa masing-masing dari 1,2 dan 3 harus dicampur sehingga terbentuk campuran yang sesuai yaitu 10,5% C_2H_5OH, 1% CH_3COOH, 88,5% H_2O. Untuk feeding Fermentor, misal diperlukan A kg distillate produk, B kg bottom produk dan C kg fresh feed 95% C_2H_5OH.

Untuk itu dilakukan langkah-langkah perhitungan sebagai berikut :

Persamaan neraca massa C_2H_5OH = 33611,760

= 0,00836393978 A + 0,01 B + 0,95 C ... pers 1

Persamaan neraca massa CH_3COOH = 3201,120 = 0,80 B ..... pers 2

Persamaan neraca massa H_2O = 283299,120

= 0,99163606022 A + 0,19 B + 0,05 C ..... pers 3

Dari pers 2 :

CH_3COOH = 3201,120 = 0,80 B

$$B = \frac{3201,120}{0,8} = 4001,400 \text{ kg}$$

Jadi total massa yang diperlukan dari produk bottom = 4001,400 kg

Harga B yang diperoleh di subtitusikan di pers 3 :

H_2O = 283299,120 = 0,99163606022 A + 0,19 B + 0,05 C

= 0,99163606022 A + 0,19 (4001,400) + 0,05 C

H_2O = 283299,120 = 0,99163606022 A + 760,266 + 0,05 C

H_2O = 283299,120 - 760,266 = 0,99163606022 A + 0,05 C

282538,854 = 0,99163606022 A + 0,05 C ..... pers 4

Harga B yang diperoleh juga disubtitusikan ke pers 1

C_2H_5OH = 33611,760 = 0,00836393978 A + 0,01 B + 0,95 C

= 0,00836393978 A + 0,01 (4001,400) + 0,95 C

C_2H_5OH = 33611,760 = 0,00836393978 A + 40,014 + 0,95 C

= 33611,760 – 40,014 = 0,00836393978 A + 0,95 C

33571,746 = 0,00836393978 A + 0,95 C ..... pers 5

Dicari harga A dengan menggunakan pers 4 dan pers 5 :

282538,854 = 0,99163606022 A + 0,05 C ..... pers 4

33571,746 = 0,00836393978 A + 0,95 C ..... pers 5

Pers 5 dikalikan dengan (0,05 / 0,95) = 0,05263157894 menjadi

(0,05/0,95) 33571,746 = (0,05/0,95) 0,00836393978 A + (0,05/0,95) 0,95 C

1766,934 = 0,00044020735 A + 0,05 C ..... pers 6

Eliminasi C dengan cara pers 4 – pers 6 adalah sebagai berikut :

282538,854 = 0,99163606022 A + 0,05 C ..... pers 4

1766,934 = 0,00044020735 A + 0,05 C ..... pers 6

280771,920 = 0,99119585287 A

$$A = \frac{280771,920}{0,99119585287} = 283265,834 \text{ kg}$$

Jadi total massa yang diperlukan dari produk distillate = 283265,834 kg

Harga C dicari dengan subtitusi harga A pada pers 4 sebagai berikut :

282538,854 = 0,99163606022 (283265,834) + 0,05 C

282538,854 = 280896,616 + 0,05 C

282538,854 – 280896,616 = 0,05 C

1642,238 = 0,05 C

$$C = \frac{1642,238}{0,05} = 32844,766 \text{ kg}$$

Jadi total massa yang diperlukan dari fresh feed 95% C_2H_5OH = 32844,766 kg

Maka untuk membuat feeding Fermentor dengan kadar 10,5% C_2H_5OH, 1% CH_3COOH dan 88,5% H_2O dicampurkan bahan-bahan dari :

Produk distillate = A kg = 283265,834 kg, dengan komposisi sebagai berikut :

C_2H_5OH = 0,00836393978 (283265,834) kg = 2369,218 kg

H_2O = 0,99163606022 (283265,834) kg = 280896,616 kg

Total = 283265,834 kg

Produk bottom = B kg = 4001,400 kg, dengan komposisi sebagai berikut :

CH_3COOH = 0,80 (4001,400) kg = 3201,120 kg

H_2O = 0,19 (4001,400) kg = 760,264 kg

C_2H_5OH = 0,01 (4001,400) kg = 40,014 kg

Total = 4001,400 kg

Fresh feed 95% C_2H_5OH =C kg = 32844,766 kg, dengan komposisi sebagai berikut :

C_2H_5OH = 0,95 (32844,766) kg = 31202,528 kg

H_2O = 0,05 (32844,766) kg = 1642,238 kg

Total = 32844,766 kg

Pengecekan hasil perhitungan :

A + B + C dicampur menjadi satu akan diperoleh feeding Fermentor dengan komposisi sebagai berikut :

C_2H_5OH = (2369,218 + 40,014 + 31202,528) kg

= 33611,760 kg ≈ 33611,760 kg

CH_3COOH = 3201,120 kg ≈ 3201,120 kg

H_2O = (280896,616 + 760,264 + 1642,238) kg

= 283299,120 kg ≈ 283299,120 kg

Dari pengecekan harga-harga C_2H_5OH, CH_3COOH dan H_2O sudah sesuai dengan harga-harga yang telah ditetapkan terlebih dahulu untuk komposisi feeding Fermentor maka perhitungan benar adanya.

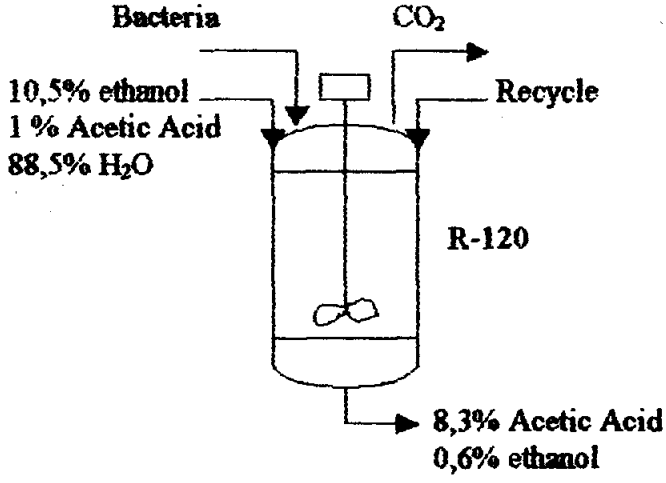
Ringkasan neraca massa Raw Mixing Tank (M-112)

Masuk		Keluar	
Recycle dari distillate (F-137)		Ke Fermentor (R-120)	
C_2H_5OH	= 2369,218 kg	C_2H_5OH	= 33611,760 kg
H_2O	= 280896,616 kg	CH_3COOH	= 3201,120 kg
	= 283265,834 kg	H_2O	= 283299,120 kg
Recycle dari bottom (F-135)			= 320112,000 kg
CH_3COOH	= 3201,120 kg		
H_2O	= 760,264 kg		
C_2H_5OH	= 40,014 kg		
	= 4001,400 kg		
Dari fresh feed 95% (F-110)			
C_2H_5OH	= 31202,528 kg		
H_2O	= 1642,238 kg		
	= 32844,766 kg		
Total	= 320112,000 kg	Total	= 320112,000 kg

II. Fermentor (R – 120)

1. Fungsi : Untuk mereaksikan C_2H_5OH dengan O_2 dari udara dengan bantuan bacteria hingga terbentuk CH_3COOH.

2. Gambar :



3. Perhitungan :

Perhitungan didasarkan dari Faith and Keyes, 1961, hlm. 13 dengan uraian perhitungan sebagai berikut :

$$C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O$$

Ethanol yang diperlukan adalah = 1950 lb x 0,95 = 1852,5 lb = 840,294 kg

$$CH_3COOH = \frac{1000}{60} \text{ kgmol}$$

$$C_2H_5OH = \frac{840,294}{46} \text{ kgmol}$$

$$C_2H_5OH \text{ yang bereaksi} = \frac{1000}{60} \times 46 \text{ kg} = 766,6666667 \text{ kg}$$

C_2H_5OH sisa, yang tak bereaksi = (840,294 – 766,6666667) kg

= 73,6273333 kg

$$\% \ C_2H_5OH \text{ yang bereaksi} = \frac{766,6666667}{840,294} \times 100\ \% = 91,237908006\ \%$$

$$O_2 \text{ yang bereaksi} = \frac{1000}{60} \times 32 \text{ kg} = 533,3333333 \text{ kg}$$

Udara yang dibutuhkan = 11000 lb

Terdiri dari 79% N_2 dan 21% O_2 (dalam % molekul)

Basis 100 kgmol udara

79% N_2 = 79 kgmol N_2 = 79 x 28 kg = 2212 kg = 76,699029126 %

21% O_2 = 21 kgmol O_2 = 21 x 32 kg = 672 kg = 23,300970874 %

= 2884 kg

11000 lb udara terdiri dari :

$$23,300970874\ \% \ O_2 = \frac{23,300970874}{100} \times 11000 \text{ lb} = 2563,10679614 \text{ lb}$$

= 1162,62524272 kg

$$76,699029126\ \% \ N_2 = \frac{76,699029126}{100} \times 11000 \text{ lb} = 8436,8932039 \text{ lb}$$

= 3826,97475728 kg

Total = 4989,6 kg = 11000 lb

$$\% \ O_2 \text{ yang bereaksi terhadap } O_2 \text{ yang ada} = \frac{533,3333333}{1162,62524272} \times 100\ \%$$

= 45,873194018 %

$$\% O_2 \text{ yang bereaksi terhadap udara yang ada} = \frac{18869,760}{4989,6} \times 100\ \%$$

$$= 10,688899577\ \%$$

Untuk 35380,800 kg C_2H_5OH 95% (sebagai hasil perkalian 35,3808 basis perhitungan II)

$$\text{Kadar 95\% ethanol} = \frac{95}{100} \times 35380,800\ kg = 33611,760\ kg$$

$$CH_3COOH \text{ yang terjadi} = \left(\frac{33611,760}{840,294} \right) \times 35380,800\ kg$$

$$= 40000,000\ kg$$

$$CH_3COOH \text{ yang ada} = (40000,000 + 3201,120)\ kg$$

$$= 43201,120\ kg$$

$$C_2H_5OH \text{ yang bereaksi} = \frac{40000,000}{60} \times 46\ kg$$

$$= 30666,666\ kg$$

$$C_2H_5OH \text{ sisa} = (33611,760 - 30666,666)\ kg = 2945,093\ kg$$

$$H_2O \text{ yang terbentuk} = \frac{40000,000}{60} \times 18\ kg$$

$$= 12000,000\ kg$$

$$H_2O \text{ yang keluar} = 283299,120 + 12000,000 = 295299,120\ kg$$

$$O_2 \text{ yang bereaksi} = \left(\frac{33611,760}{840,294} \right) \times 18869,760\ kg$$

$$= 21333,333\ kg$$

O_2 yang ada dari udara = $\frac{100}{45{,}873194018}$ x 21333,333 kg

= 46505,010 kg = 23,300970874 % berat

N_2 dari udara = $\frac{76{,}699029126}{23{,}300970874}$ x 46505,010 kg

= 153078,990 kg

Udara = $O_2 + N_2$

= (46505,010 + 153078,990) kg

= 199584,000 kg

O_2 sisa = (46505,010 – 21333,333) kg

= 25171,676 kg

Volume bahan liquid masuk Fermentor = $\frac{320112{,}000}{0{,}97648}$ liter

= 327822,382 liter

= 86610,933 gallon

Jumlah media bacteria = $\frac{86610{,}933}{2500}$ x 7 lb (Presscott, 1987, hlm. 441)

= 242,511 lb

= 110,003 kg ≈ 110,003 liter

NH_4OH = 0,25 % dari jumlah media bacteria (Presscott, 1987, hlm. 431)

= $\frac{0{,}25}{100}$ x 110,003 kg

= 0,275 kg

Reaksi peruraian NH_4OH adalah sebagai berikut :

$$NH_4OH \longrightarrow NH_3 + H_2O$$

$$NH_3 = \frac{17}{35}(0{,}275)\ kg = 0{,}134\ kg$$

$$H_2O = \frac{18}{35}(0{,}275)\ kg = 0{,}141\ kg$$

Reaksi pembentuk cell bacteria (Battley, 1979, hlm. 132)

$$1{,}300\ C_2H_5OH + 2{,}406\ O_2 + 0{,}198\ NH_3 \longrightarrow 1{,}339\ CH_{1{,}704}\ N_{0{,}419}\ O_{0{,}408} + 1{,}261\ CO_2 + 3{,}049\ H_2O$$

$$NH_3 = \frac{0{,}134}{17}\ kgmol$$

$$C_2H_5OH \text{ yang diperlukan} = \frac{1{,}300}{0{,}198}\left(\frac{0{,}134}{17}\right)46\ kg$$

$$= 2{,}373\ kg$$

$$O_2 \text{ yang diperlukan} = \frac{2{,}406}{0{,}198}\left(\frac{0{,}134}{17}\right)32\ kg$$

$$= 3{,}055\ kg$$

$$\text{Cell yang terjadi} = \frac{1{,}339}{0{,}198}\left(\frac{0{,}134}{17}\right)26{,}098\ kg$$

$$= 1{,}387\ kg$$

$$CO_2 \text{ yang terjadi} = \frac{1{,}262}{0{,}198}\left(\frac{0{,}134}{17}\right)44\ kg$$

$$= 2{,}204\ kg$$

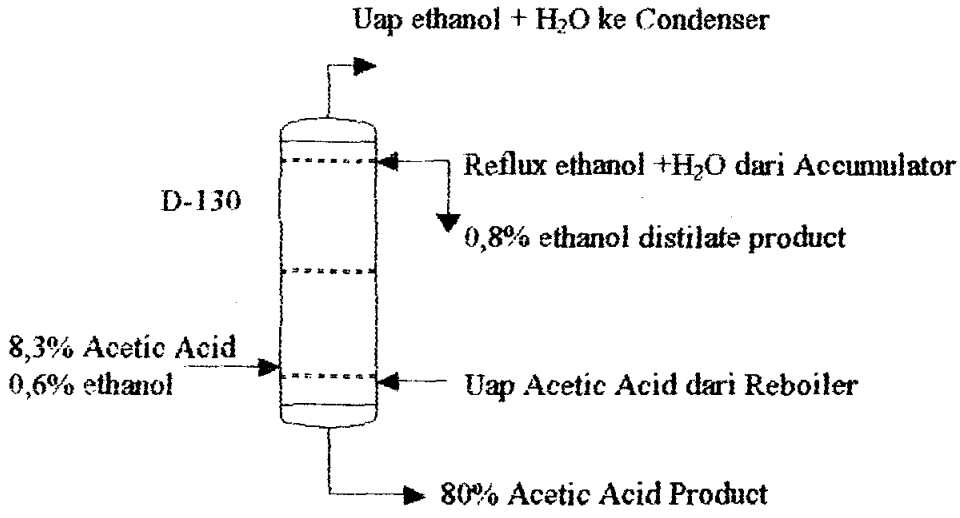
Ringkasan neraca massa Fermentor (R-120)

Masuk		Keluar	
Dari (F-110) dan (D-130) Recycle		Ke Distilator (D-130)	
C_2H_5OH	= 33611,760 kg	CH_3COOH	= 43201,120 kg
CH_3COOH	= 3201,120 kg	C_2H_5OH	= 2945,093 kg
H_2O	= 283299,120 kg	H_2O	= 295408,588 kg
	= 320112,000 kg	Bacteria	= 1,387 kg
Media bacteria dari laboratorium			= 341556,188 kg
C_2H_5OH	= 2,373 kg	Ke udara	
Bacteria	= 0,206 kg	O_2	= 25168,621 kg
NH_4OH	= 0,275 kg	N_2	= 153078,990 kg
H_2O	= 107,148 kg	CO_2	= 2,204 kg
	= 110,003 kg		= 178249,815 kg
Udara			
O_2	= 46505,010 kg		
N_2	= 153078,990 kg		
	= 199584,000 kg		
Total	= 519806,003 kg	Total	= 519806,003 kg

III. Distillator (D – 130)

1. Fungsi : Untuk memurnikan larutan 8,3% Acetic Acid menjadi produk 80% Acetic Acid.

2. Gambar :



Senyawa	Berat (kg)	Berat molekul	Jumlah molekul	Molekul fraction
C_2H_5OH	2945,093	46	64,024	0,00372326
CH_3COOH	43201,120	60	720,019	0,04187219
H_2O	295408,588	18	16411,588	0,95440455
Total	341554,801		17195,631	1,00000

Bottom terdiri dari :

Semua fraction CH_3COOH ke Bottom = 720,019 kgmol = 80 % massa

= 43201,120 kg

$$1\%\text{ berat } C_2H_5OH = \frac{1}{80} \times 43201{,}120 \text{ kg}$$

$$= 540{,}014 \text{ kg} = 11{,}739 \text{ kgmol}$$

$$19\ \%\ \text{berat}\ H_2O = \frac{19}{80} \times 43201{,}120\ \text{kg}$$

$$= 10260{,}266\ \text{kg} = 570{,}015\ \text{kgmol}$$

Total molekul ke Bottom = (720,019 + 30,000 + 570,015) kgmol

= 1320,034 kgmol

mol fraksi di Bottom :

CH_3COOH = 720,019 / 1320,034 = 0,54545455

H_2O = 570,015 / 1320,034 = 0,43181818

C_2H_5OH = 30,000 / 1320,034 = 0,02272727

Neraca massa komponen C_2H_5OH = $F . X_F = D.x_D + Bx_B$

(17195,631 x 0,00372326) = Dx_D + (1320,034 x 0,02272727)

64,024 = Dx_D + 30,000

Dx_D = 64,024 – 11,739

= 52,284 kgmol

Neraca massa komponen H_2O = $F.X_F = Dx_D + Bx_B$

(17195,631 x 0,95440455) = Dx_D + (1320,034 x 0,43181818)

16411,588 = Dx_D + 570,015

Dx_D = 16411,588 – 570,015

= 15841,573 kgmol

Jadi komposisi Distillate

C_2H_5OH = 52,284 kgmol = 0,00328959 mol fraction

H_2O = 15841,573 kgmol = 0,99671041 mol fraction

= 15893,858 kgmol = 1,00000 mol fraction

Komposisi mol fraction di Distillator

Senyawa	Boiling point	Mol fraction Feed	Mol fraction Distilate	Mol fraction Bottom
CH_3COOH	118,1°C	0,04187219	-	0,54545455
C_2H_5OH	78,3°C	0,00372326	0,00328959	0,02272727
H_2O	100°C	0,95440455	0,99671041	0,43181818
Total			1,000	1,000

Menentukan kondisi operasi feed masuk Distillator

Perhitungan sesuai Kern hlm.324

Suhu bubble point feed di trial = 100,5°C

Tekanan operasi di trial = 760 mmHg

Komponen	Mol fraksi = x	Pi (mmHg)	ki = pi/p (p = 760 mmHg)	y_i = ki.xi
CH_3COOH	0,04187219	415	0,5460526	0,02286442
C_2H_5OH	0,00372326	1760	2,3158	0,008622286
H_2O	0,95440455	773,68	1,018	0,9715838
				1,003 ≈ 1

Bubble point Distillate 99,9°C

Tekanan 1 atm = 760 mmHg

Komponen	Mol fraksi = x	Pi (mmHg)	ki = pi/p	y_i = ki.xi
C_2H_5OH	0,00328959	1712	2,2526316	0,00741023
H_2O	0,99671041	757,29	0,99643421	0,99315635
				1,0005 ≈ 1

Bubble point Bottom 106°C

Tekanan 1 atm = 760 mmHg

Komponen	Mol fraksi = x	Pi (mmHg)	ki = pi/p	$y_i = ki.xi$
CH_3COOH	0,54545455	531,937173	0,699917	0,381773
C_2H_5OH	0,02272727	2200	2,89474	0,065789
H_2O	0,43181818	986,865672	1,2985075	0,5607191
				1,008 ≈ 1

Dew point Bottom 109°C

Tekanan 1 atm = 760 mmHg

Komponen	Mol fraksi = x	Pi (mmHg)	ki = pi/p	$y_i = y_{Di} / xi$
CH_3COOH	0,54545455	588,481675	0,774318	0,7044322
C_2H_5OH	0,02272727	2440,00	3,2105	0,0070790
H_2O	0,43181818	1100,298507	1,4477612	0,29826616
				1,00977 ≈ 1

Dew pont Distillate 100°C

Tekanan 1 atm = 760 mmHg

Komponen	Mol fraksi = x	Pi (mmHg)	ki = pi/p	$y_i = xi / ki$
C_2H_5OH	0,00328959	1720	2,26315789	0,00145354
H_2O	0,99671041	760	1	0,99671041
				0,9982 ≈ 1

Mencari harga reflux ratio minimum (R min)

(Cara Rao & Raviprasad : Chemical Engineering, October, 12, 1987)

$$R\ min = \frac{1}{(X_{F,Lk})_{eff}\,[(\alpha_{Lk,Hk})_{av} - 1]}$$

dimana :

$$(X_{F,Lk})_{eff} = \frac{X_{F,Lk}}{X_{F,Lk} + X_{F,Hk}}$$

$$= \frac{0,00372326}{0,00372326 + 0,04187219}$$

$$= \frac{0,00372326}{0,04559545} = 0,0816586$$

$\alpha_{Lk,Hk}$ atas = distillate yang dew point (ki)

$$= \frac{2,26315789}{1} = 2,26315789$$

$\alpha_{Lk,Hk}$ bawah = bottom yang dew point (ki)

$$= \frac{3,2105}{1,4477612} = 2,21756$$

$$(\alpha_{Lk,Hk})_{av} = \sqrt{(\alpha_{Lk,Hk})\ \text{atas}\ \ (\alpha_{Lk,Hk})\ \text{bawah}}$$

$$= \sqrt{(2,26315789)\ (2,21756)} = 2,24024$$

$$R\ min = \frac{1}{(0,0816586)\ [(2,24024) - 1]} = 9,87398$$

R op = 1,1 – 1,5 R min (Perry ed. 6)

= 1,2 – 2,0 R min (Ludwig)

Diambil :

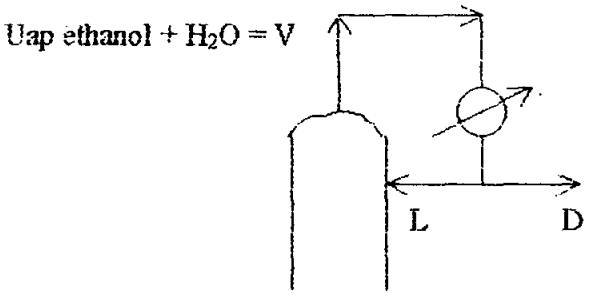
R op = 1,2 R min

= 1,2 (9,873982) = 11,8488 = L/D = R

L = R x D

L = 11,8488 x D

Total condenser



Komposisi reflux

Komponen	D kgmol	L = 11,8488 x D	V = (11,8488 + 1) D
C_2H_5OH	52,284	619,503	671,787
H_2O	15841,573	187703,630	203545,203

Liquid = L

C_2H_5OH = 619,503 x 46 kg = 28497,138 kg

H_2O = 187703,630 x 18 kg = 3378665,340 kg

Total = 3407162,478 kg

Distillate = D

C_2H_5OH = 52,284 x 46 kg = 2405,079 kg

H_2O = 15841,573 x 18 kg = 285148,322 kg

Total = 316889,145 kg

Vapour = V = L + D

C_2H_5OH = (28497,138 + 2405,079) kg = **30902,217 kg**

H_2O = (3378665,340 + 285148,322) kg = **3663813,662 kg**

Total = **3694715,879 kg**

Bottom

CH_3COOH = 720,019 x 60 kg = 43201,120 kg

H_2O = 570,015 x 18 kg = 10260,206 kg

C_2H_5OH = 30,000 x 46 kg = 540,014 kg

Total = 54001,400 kg

Komposisi produk CH_3COOH

Komposisi produk CH_3COOH yang dijual = produk bottom – recycle ke Fermentor

(Kebutuhan untuk recycle disajikan di perhitungan Material Mixing Tank)

CH_3COOH = (43201,120 – 3201,120) kg = 40000,000 kg

H_2O = (10260,266 – 760,266) kg = 9500,000 kg

C_2H_5OH = (540,014 – 40,014) kg = 500,000 kg

= 50000,000 kg

Komposisi waste (buangan)

Komposisi waste = produk distilate – untuk recycle ke Fermentor

(Kebutuhan untuk recycle disajikan di perhitungan Material Mixing Tank)

C_2H_5OH = (2405,079 – 2369,218) kg = 35,861 kg

H_2O = (285148,322 – 280896,616) kg = 4251,706 kg

Total = 4287,567 kg

Ringkasan neraca massa Distillator (D-130)

Masuk		Keluar	
Dari Heater (E-126)		Distillate ke (F-137)	
C_2H_5OH	= 2945,093 kg	Recycle ke Fermentor (R-120)	
CH_3COOH	= 43201,120 kg	C_2H_5OH	= 2369,218 kg
H_2O	= 295408,588 kg	H_2O	= 280896,616 kg
	= 341554,801 kg		= 283265,834 kg
		Waste	
		C_2H_5OH	= 35,861 kg
		H_2O	= 4251,706 kg
			= 4287,567 kg
		Bottom	
		Recycle ke Fermentor (R-120)	
		CH_3COOH	= 3201,120 kg
		H_2O	= 760,266 kg
		C_2H_5OH	= 40,014 kg
			= 4001,400 kg
		Dijual 80% Acetic Acid	
		CH_3COOH	= 40000,000 kg
		H_2O	= 9500,000 kg
		C_2H_5OH	= 500,000 kg
			= 50000,000 kg
Total	= 341554,801 kg	Total	= 341554,801 kg

APPENDIX B

PERHITUNGAN NERACA PANAS

APPENDIX B

PERHITUNGAN NERACA PANAS

Kapasitas produksi : 50.000 kg 80% Acetic Acid

Satuan panas : kilokalori (kkal)

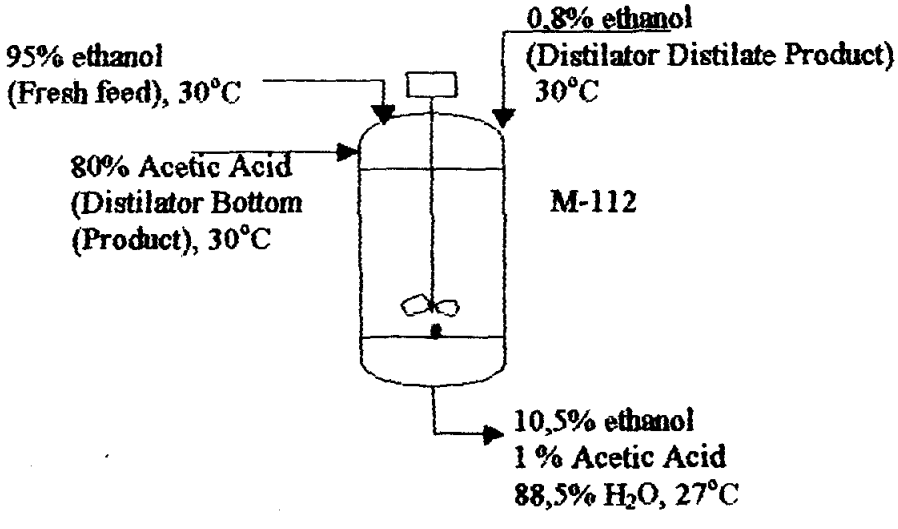
Basis waktu : 1 hari

Suhu reference : 25°C

I. Raw Material Mixing Tank (M – 112)

1. Fungsi : Untuk mencampur 95 % larutan C_2H_5OH dengan Acetic Acid dan H_2O sehingga membentuk campuran 10,5% C_2H_5OH, 1 % CH_3COOH dan 88,5% H_2O.

2. Gambar :



3. Perhitungan :

Ethalpy bahan masuk dari Distillate pada 30°C

$\Delta H.C_2H_5OH$ = 2369,218 x 0,680 (30-25) kkal = 8055,341 kkal

$\Delta H.H_2O$ = 280896,616 x 1 (30-25) kkal = 1404483,080 kkal

Total = 1412538,421 kkal

Enthalpy bahan masuk dari bottom pada 30°C

$\Delta H.C_2H_5OH$ = 40,014 x 0,680 (30-25) kkal = 136,048 kkal

$\Delta H.CH_3COOH$ = 3201,120 x 0,522 (30-25) kkal = 8354,923 kkal

$\Delta H.H_2O$ = 760,264 x 1 (30-25) kkal = 3801,320 kkal

Total = 12292,291 kkal

Ethalpy bahan masuk dari fresh feed pada 30°C

$\Delta H.C_2H_5OH$ = 31202,528 x 0,680 (30-25) kkal = 106088,595 kkal

$\Delta H.H_2O$ = 1642,238 x 1 (30-25) kkal = 8211,190 kkal

Total = 114299,785 kkal

Total enthalpy bahan masuk = 1539130,497 kkal

Enthalpy bahan keluar

Dari hasil percobaan, pada pencampuran terjadi penurunan suhu dari 30°C menjadi 27°C = suhu bahan keluar.

Enthalpy bahan keluar pada 27°C

$\Delta H.C_2H_5OH$ = 33611,760 x 0,680 (27-25) kkal = 45711,994 kkal

$\Delta H.CH_3COOH$ = 43201,120 x 0,522 (27-25) kkal = 45101,969 kkal

$\Delta H.H_2O$ = 283299,120 x 1 (27-25) kkal = 566598,240 kkal

Total = 657412,203 kkal

Karena udara luar suhunya lebih tinggi dari suhu bahan setelah pencampuran atau 30°C > 27°C, maka terjadi penyerapan panas dari udara sekeliling sebesar

= (1539130,497 – 657412,203) kkal = 881718,294 kkal

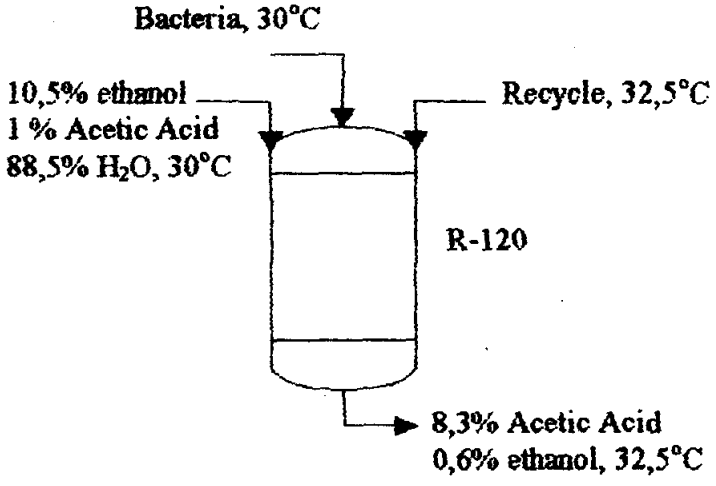
Ringkasan neraca panas Raw Material Mixing Tank (M-112)

Masuk		Keluar	
$\Delta H.C_2H_5OH$	= 8055,341 kkal	$\Delta H.C_2H_5OH$	= 45711,994 kkal
$\Delta H.H_2O$	= 1404483,080 kkal	$\Delta H.CH_3COOH$	= 45101,969 kkal
	= 1412538,421 kkal	$\Delta H.H_2O$	= 566598,240 kkal
Dari bottom			= 657412,203 kkal
$\Delta H.C_2H_5OH$	= 136,048 kkal	Panas yang diserap dari udara	= 881718,294 kkal
$\Delta H.CH_3COOH$	= 8354,923 kkal		
$\Delta H.H_2O$	= 3801,320 kkal		
	= 12292,291 kkal		
Fresh feed			
$\Delta H.C_2H_5OH$	= 106088,595 kkal		
$\Delta H.H_2O$	= 8211,190 kkal		
	= 114299,785 kkal		
Total	= 1539130,497 kkal	Total	= 1539130,497 kkal

II. Fermentor (R – 120)

1. Fungsi : Untuk mereaksikan C_2H_5OH dengan O_2 dari udara dengan bantuan bacteria hingga terbentuk CH_3COOH

2. Gambar :



Enthalpy 10% ethanol dan 1% acetic acid masuk dari M-112 pada 30°C

$\Delta H.C_2H_5OH$ = 33611,760 x 0,680 (30-25) kkal = 114279,984 kkal

$\Delta H.CH_3COOH$ = 43201,120 x 0,522 (30-25) kkal = 8354,923 kkal

$\Delta H.H_2O$ = 283299,120 x 1 (30-25) kkal = 1416495,600 kkal

Total = 1539130,507 kkal

Enthalpy media bacteria masuk pada 30°C

$\Delta H.C_2H_5OH$ = 2,373 x 0,680 (30-25) kkal = 8,068 kkal

$\Delta H.$bacteria = 0,206 x 1,0 (30-25) kkal = 1,030 kkal

$\Delta H.NH_4OH$ = 0,275 x 1,0 (30-25) kkal = 1,375 kkal

$\Delta H.H_2O$ = 107,148 x 1,0 (30-25) kkal = 535,740 kkal

Total = 546,213 kkal

Enthalpy udara masuk pada 30°C

$\Delta H.O_2$	= 46505,010 x 0,22 (30-25) kkal	= 51155,511 kkal
$\Delta H.N_2$	= 153078,990 x 0,25 (30-25) kkal	= 191348,737 kkal
	Total	= 242504,248 kkal

Total enthalpy bahan masuk = 1782180,968 kkal

Enthalpy bahan keluar pada 32,5°C

$\Delta H.CH_3COOH$	= 43201,120 x 0,522 (32,5-25) kkal	= 169132,385 kkal
$\Delta H.C_2H_5OH$	= 2945,093 x 0,680 (32,5-25) kkal	= 15019,974 kkal
$\Delta H.H_2O$	= 295408,588 x 1 (32,5-25) kkal	= 2215564,410 kkal
ΔH.bacteria	= 1,387 x 1 (32,5-25) kkal	= 10,402 kkal
$\Delta H.O_2$	= 25168,621 x 0,22 (32,5-25) kkal	= 41528,225 kkal
$\Delta H.N_2$	= 153078,990 x 0,25 (32,5-25) kkal	= 287023,106 kkal
$\Delta H.CO_2$	= 2,204 x 0,21 (32,5-25) kkal	= 3,471 kkal
	Total	= 2728281,973 kkal

Panas reaksi pada 25°C (pada keadaan standard)

Reaksi : $C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O$

Panas reaksi standard (25°C) sesuai Hougen and Watson, 1954,hlm. 311 adalah :

$$\left(\Delta H_{Reaction} = \Sigma Hf_{(Products)} - \Sigma Hf_{(Reactans)} \right)_{25^\circ C}$$

atau :

$\Delta H_{R\,25^\circ C}$ = [- 116200 + (- 68317,4) – (- 66350)] kkal/kgmol

= - 118167,4 kkal/kgmol

Jumlah molekul = $\frac{40000}{60}$ (- 118167,4)kkal

= - 78778266,667 kkal (negatip, mengeluarkan panas)

Panas reaksi pada 32,5°C = 305,5°k sesuai Smith Van Ness, 1959, hlm.145

$$\Delta H^\circ_{305,5} = \Delta H^\circ_{298} + \left[\sum_{\text{Products}} (n\,Cp, \text{mass}) - \sum_{\text{Reactans}} (n\,Cp, \text{mass}) \right] (305,5 - 298)$$

$\Delta H^\circ_{305,5}$ = (78778266,667 + 2728281,973 – 1782180,968) kkal

= 79724367,672 kkal

Total enthalpy yang diharapkan pada suhu 32,5°C = total enthalpy bahan keluar

Enthalpy bahan keluar pada T°C

$\Delta H.CH_3COOH$	= 43201,120 x 0,522 (T) kkal	=	22550,98646 T kkal
$\Delta H.C_2H_5OH$	= 2945,093 x 0,680 (T) kkal	=	2002,66324 T kkal
$\Delta H.H_2O$	= 295408,588 x 1 (T) kkal	=	295408,588 T kkal
ΔH.bacteria	= 1,387 x 1 (T) kkal	=	1,387 T kkal
$\Delta H.O_2$	= 25168,621 x 0,22 (T) kkal	=	5537,09662 T kkal
$\Delta H.N_2$	= 153078,990 x 0,25 (T) kkal	=	38269,7475 T kkal
$\Delta H.CO_2$	= 2,204 x 0,21 (T) kkal	=	0,46284 T kkal
	Total	=	363770,92984 T kkal
		=	80560447,635 kkal

T = 221,459278426

T_2 = 246,459278426°C

10 hari proses untuk tiap batch, maka rata-rata/hari timbul panas

$$= \frac{78778266,667}{10} \text{ kkal} = 7877826,667 \text{ kkal}$$

Panas yang harus dihilangkan = 7877826,667 + 1782180,968 - 2728281,973

= 9660007,635

Total = 363770,92984 T kkal

= 9660007,635 kkal

$$T = \frac{9660007,635}{363770,92984} \text{ °C} = 26,5551940592 \text{ °C}$$

Suhu bahan keluar = (26,5551940592 + 25) °C

= 51,5551940592 °C

Jadi panas yang harus dihilangkan

= $\Delta H_{R\,25^\circ C}$ + total enthalpy bahan masuk – total enthalpy bahan keluar

= (78778266,667 + 1782180,968 - 2728281,973) kkal

= 77832165,662 kkal

Jumlah air pendingin

Digunakan air pendingin masuk pada suhu 30°C keluar pada suhu 45°C (Ulrich, 1984, hlm.159)

$$\text{Jumlah air pendingin} = \frac{77832165,662}{1\,(45 - 30)} \text{ kg}$$

= 5188811,04413 kg

Enthalpy air pendingin

Enthalpy air pendingin masuk

$\Delta H.H_2O$ = 5188811,04413 x 1 (30-25) kkal = 25944055,220 kkal

Enthalpy air pendingin keluar

$\Delta H.H_2O$ = 5188811,04413 x 1 (45-25) kkal = 103776220,882 kkal

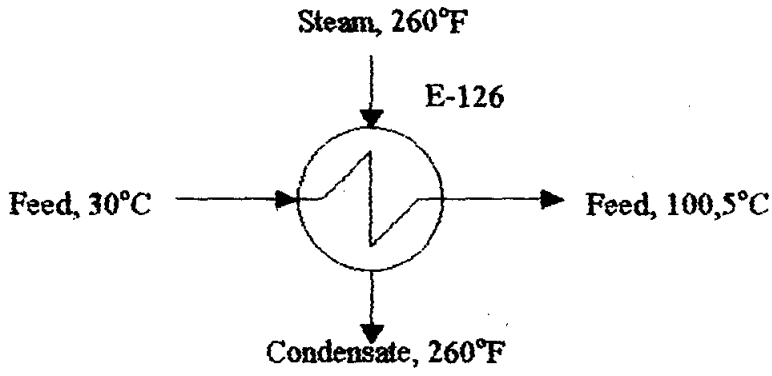
Ringkasan neraca panas Fermentor (R-120)

Masuk			Keluar		
Dari M-112			Ke Distilator		
$\Delta H.C_2H_5OH$	=	114279,984 kkal	$\Delta H.CH_3COOH$	=	169132,385 kkal
$\Delta H.CH_3COOH$	=	8354,923 kkal	$\Delta H.C_2H_5OH$	=	15019,974 kkal
$\Delta H.H_2O$	=	1416495,600 kkal	$\Delta H.H_2O$	=	2215564,410 kkal
	=	1539130,507 kkal	$\Delta H.bacteria$	=	10,402 kkal
Media bacteria			$\Delta H.O_2$	=	41528,225 kkal
$\Delta H.C_2H_5OH$	=	8,068 kkal	$\Delta H.N_2$	=	287023,106 kkal
$\Delta H.bacteria$	=	1,030 kkal	$\Delta H.CO_2$	=	3,471 kkal
$\Delta H.NH_4OH$	=	1,375 kkal		=	2728281,973 kkal
$\Delta H.H_2O$	=	535,740 kkal	Air pendingin		
	=	546,213 kkal	$\Delta H.H_2O$	=	103776220,882 kkal
Udara					
$\Delta H.O_2$	=	51155,511 kkal			
$\Delta H.N_2$	=	191348,737 kkal			
	=	242504,248 kkal			
$\Delta H_{R25^\circ C}$	=	78778266,667 kkal			
Air pendingin					
$\Delta H.H_2O$	=	25944055,220 kkal			
Total	=	106504502,855 kkal	Total	=	106504502,855 kkal

III. Heater (E – 126)

1. Fungsi : Untuk memanaskan feed yang akan masuk ke Distillator dari 30°C menjadi 100,5°C dengan menggunakan steam.

2. Gambar :



Enthalpy bahan masuk pada 30°C

$\Delta H.C_2H_5OH$ = 2945,093 x 0,680 (30-25) kkal = 10013,316 kkal

$\Delta H.CH_3COOH$ = 43201,120 x 0,522 (30-25) kkal = 112754,923 kkal

$\Delta H.H_2O$ = 295408,588 x 1 (30-25) kkal = 1477042,940 kkal

Total = 1599811,179 kkal

Enthalpy bahan keluar pada 100,5°C

$\Delta H.C_2H_5OH$ = 2945,093 x 0,680 (100,5-25) kkal = 151201,075 kkal

$\Delta H.CH_3COOH$ = 43201,120 x 0,522 (100,5-25) kkal = 1702599,340 kkal

$\Delta H.H_2O$ = 295408,588 x 1 (100,5-25) kkal = 22303348,394 kkal

Total = 24157148,809 kkal

Panas yang harus ditambahkan = (24157148,809 - 1599811,179) kkal

= 22557337,630 kkal

Heat losses diasumsikan 5% = $\frac{5}{100}$ (22557337,630) kkal

= 1127866,882 kkal

Total panas yang harus diberikan steam = (22557337,630 + 1127866,882) kkal

= 23685204,512 kkal

= 93988906,7936 Btu

Digunakan steam 260°F, tekanan 35,429 lb force/in^2

(Mc Cabe, 1974, hlm.915)

i_x = 228,60 Btu/lb

λ = 938,7 Btu/lb

i_y = 1167,3 Btu/lb

Jumlah steam yang diperlukan

Jumlah steam = $\frac{93988906,7936}{938,7}$ lb

= 100126,671773 lb

ΔH.steam = 100126,671773 x 1167,3 Btu = 116877863,960 Btu

= 29453221,718 kkal

ΔH.condensate = 100126,671773 x 228,6 Btu = 22888957,1673 Btu

= 5768017,206 kkal

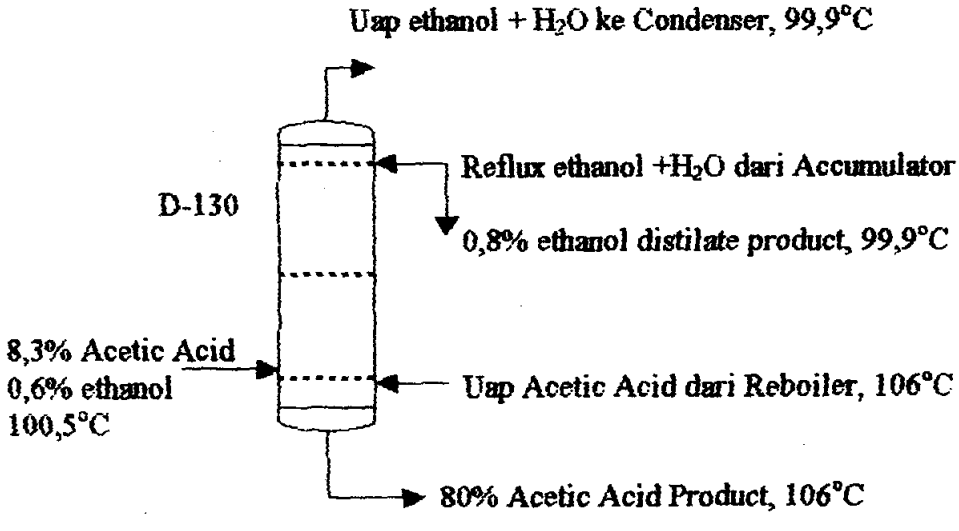
Ringkasan neraca panas Heater (E-126)

Masuk		Keluar	
$\Delta H.C_2H_5OH$	= 10013,316 kkal	$\Delta H.C_2H_5OH$	= 151201,075 kkal
$\Delta H.CH_3COOH$	= 112754,923 kkal	$\Delta H.CH_3COOH$	= 1702599,340 kkal
$\Delta H.H_2O$	= 1477042,940 kkal	$\Delta H.H_2O$	= 22303348,394 kkal
	= 1599811,179 kkal		= 24157148,809 kkal
ΔH.steam	= 29453221,718 kkal	ΔH.condensate	= 5768017,206 kkal
		Heat losses	= 1127866,882 kkal
Total	= 31053032,897 kkal	Total	= 31053032,897 kkal

IV. Distillator (D – 130)

1. Fungsi : Untuk memurnikan larutan 8,3% Acetic Acid menjadi produk 80% Acetic Acid.

2. Gambar :



Enthalpy bahan masuk (ΔH_F) pada 100,5°C

$\Delta H.C_2H_5OH$ = 2945,093 x 0,680 (100,5-25) kkal = **151201,075 kkal**

$\Delta H.CH_3COOH$ = 43201,120 x 0,522 (100,5-25) kkal = **1702599,340 kkal**

$\Delta H.H_2O$ = 295408,588 x 1 (100,5-25) kkal = **22303348,394 kkal**

Total = **24157148,809 kkal**

Enthalpy produk atas keluar (distillate) = ΔH_D pada 99,9°C

$\Delta H.C_2H_5OH$ = 2405,079 x 0,680 (99,9-25) kkal = **122495,484 kkal**

$\Delta H.H_2O$ = 285148,322 x 1 (99,9-25) kkal = **21357609,318 kkal**

Total = **21480104,802 kkal**

Enthalpy produk bawah keluar (bottom) = ΔH_B pada 106°C

$\Delta H.CH_3COOH$ = 43201,120 x 0,522 (106-25) kkal = **1826629,756 kkal**

$\Delta H.C_2H_5OH$ = 540,014 x 0,680 (106-25) kkal = **29743,971 kkal**

$\Delta H.H_2O$ = 10260,266 x 1 (106-25) kkal = **831081,546 kkal**

Total = **2687455,273 kkal**

Penentuan beban condenser

Enthalpy vapor keluar distillatory pada 99,9°C masuk ke condenser pada phase gas = ΔH_v

$\Delta H.C_2H_5OH$ = 30902,217 x [(99,9-25) 0,680 + 204,26] kkal = **7885998,561 kkal**

$\Delta H.H_2O$ = 3663813,662 x [(99,9-25) 1 + 540,5] kkal = **2254710927,568 kkal**

Total = **249900882,129 kkal**

Enthalpy liquid keluar condenser pada suhu 99,9°C = ΔH_L

$\Delta H C_2H_5OH$ 30902,217 x 0,680 (99,9-25) kkal = 1573911,716 kkal

$\Delta H H_2O$ = 3663813,662 x 1 (99,9-25) kkal = 20554031281,150 kkal

Total = **30803513,866 kkal**

Beban condenser = $Q_C = \Delta H_V - \Delta H_L$

= (249900882,129 - 30803513,866) **kkal**

= 219097368,263 kkal

Panas yang diperlukan dri reboiler = Q_R

Sesuai dengan Kern, hlm. 492, maka

$\Delta H_F + Q_R = \Delta H_D + \Delta H_B + Q_C$ + **panas hilang**

Panas hilang diasumsikan 5% Q_R, maka

$\Delta H_F + Q_R = \Delta H_D + \Delta H_B + Q_C + 0,05\ Q_R$

24157148,809 + Q_R = 21480104,802 + 2687455,273 + **219097368,263** + 0,05 Q_R

0,95 Q_R = 219107779,529

Q_R = 230639767,925 kkal

Heat losses 5 % = $\frac{5}{100}$ (230639767,925) **kkal**

= 11531988,396 kkal

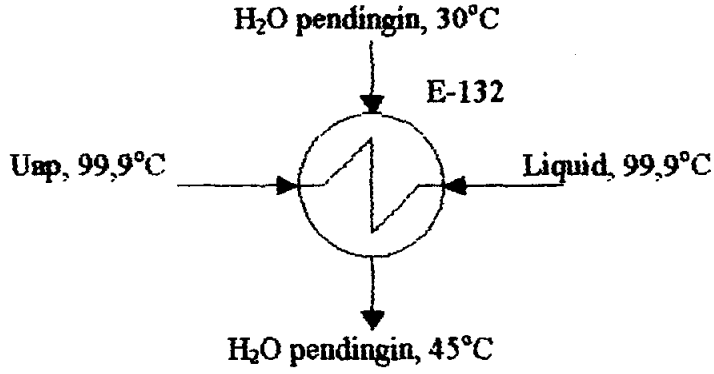
Ringkasan neraca panas Distillator (D-130)

Masuk			Keluar		
			Distilate		
$\Delta H.C_2H_5OH$	=	151201,075 kkal	$\Delta H.C_2H_5OH$	=	122495,484 kkal
$\Delta H.CH_3COOH$	=	1702599,340 kkal	$\Delta H.H_2O$	=	21357609,318 kkal
$\Delta H.H_2O$	=	22303348,394 kkal		=	21480104,802 kkal
	=	24157148,809 kkal	Gas pada 99,9°C ke coudenser		
Q_R	=	230639767,925 kkal	$\Delta H.C_2H_5OH$	=	7885998,561 kkal
Liquid pada 99,9°C			$\Delta H.H_2O$	=	2254710927,568 kkal
$\Delta H.C_2H_5OH$	=	1573911,716 kkal		=	249900882,129 kkal
$\Delta H.H_2O$	=	20554031281,150 kkal	Bottom pada 106°C		
	=	30803513,866 kkal	$\Delta H.CH_3COOH$	=	1826629,756 kkal
			$\Delta H.C_2H_5OH$	=	29743,971 kkal
			$\Delta H.H_2O$	=	831081,546 kkal
				=	2687455,273 kkal
			Heat losses	=	11531988,396 kkal
Total	=	285600430,600 kkal	Total	=	285600430,600 kkal

V. Condenser (E – 132)

1. Fungsi : Untuk mengembunkan uap dari Distilator dengan menggunakan air pendingin.

2. Gambar :



Jumlah air pendingin yang diperlukan

Jumlah panas yang harus diserap telah disajikan di perhitungan neraca panas Distillator yaitu sebesar = 2190973368,263 kkal

Air pendingin masuk pada 30°C dan keluar pada 45°C

(Ulrich, 1985, hlm. 149)

$$\text{Maka jumlah air pendingin} = \frac{2190973368{,}263}{1\,(45-30)} \text{ kg}$$

$$= 14606491{,}2175 \text{ kg}$$

Enthalpy air pendingin

$\Delta H.H_2O$ masuk = 14606491,2175 x 1 (30-25) kkal = 73032456,087 kkal

$\Delta H.H_2O$ keluar = 14606491,2175 x 1 (45-25) kkal = 292129824,350 kkal

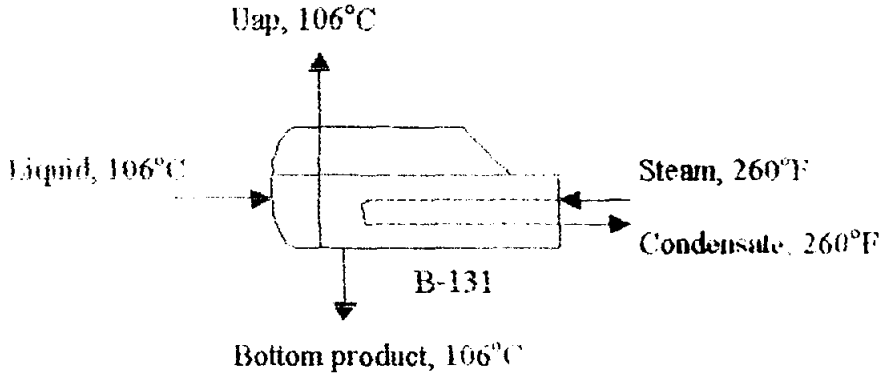
Ringkasan neraca panas Condenser (E-132)

Masuk		Keluar	
Enthalpy vapor = ΔH_v		Enthalpy liquid ΔH_l	
$\Delta H_v C_2H_5OH$	= 7885998,561 kkal	$\Delta H_l C_2H_5OH$	= 1573911,716 kkal
$\Delta H_v H_2O$	= 2254710927,568 kkal	$\Delta H_l H_2O$	= 205541031281,150 kkal
	= 249900882,129 kkal		= 30803513,866 kkal
Air pendingin		Air pendingin	
$\Delta H_l H_2O$	= 73032456,087 kkal	$\Delta H_l H_2O$	= 292129824,350 kkal
Total	= 322933338,216 kkal	Total	= 322933338,216 kkal

VI. Reboiler (B – 131)

1. Fungsi : Untuk menguapkan sebagian bottom product dengan menggunakan steam.

2. Gambar :



Jumlah steam yang diperlukan

Dari perhitungan neraca panas yang disajikan di perhitungan neraca panas Distillator diperoleh panas yang harus diberikan oleh Reboiler = Q_R = 230639767,925 kkal

= 915237174,305 Btu

Digunakan steam 260°F, tekanan 35,429 lb force/in^2

(Mc Cabe, 1974, hlm.915)

i_x = 228,60 Btu/lb

λ = 938,7 Btu/lb

i_y = 1167,3 Btu/lb

Jumlah steam yang diperlukan

$$\text{Jumlah steam} = \frac{915237174,305}{938,7} \text{ lb} = 975004,979551 \text{ lb}$$

ΔH.steam = 975004,979551 x 1167,3 Btu = 1138123312,620 Btu

= 286807074,783 kkal

ΔH.condensate = 975004,979551 x 228,6 Btu = 222886138,325 Btu

= 56167306,858 kkal

Ringkasan neraca panas Reboiler (B-131)

Masuk		Keluar	
Steam 260°F		Panas yang diserap	
ΔH.steam	= 286807074,783 kkal		= 230639767,925 kkal
		ΔH.condensate	= 56167306,858 kkal
Total	= 286807074,783 kkal	Total	= 286807074,783 kkal

APPENDIX C

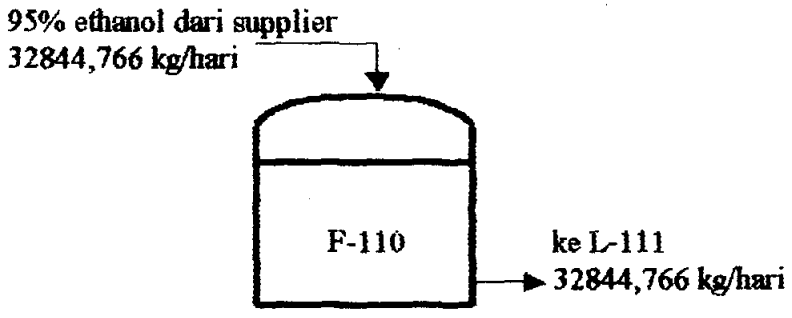
PERHITUNGAN SPESIFIKASI PERALATAN

APPENDIX C

PERHITUNGAN SPESIFIKASI PERALATAN

01. 95% ETHANOL STORAGE (F – 110)

Gambar 95% ethanol storage dan aliran massa



Fungsi : Untuk menampung ethanol fresh feed dari pabrik Alkohol dan Spiritus Mojokerto.

Type : Silinder tegak, tutup atas berbentuk ellipsoidal, bagian bawah datar.

Kebutuhan perhari = 32844,766 kg

Density ethanol = 0,79555 kg/lt

= 49,642 lb/cuft (Perry edisi VI, hlm. 3.89)

Perhitungan :

Waktu penampungan seminggu operasi atau 5 hari kerja

(Vilbrandt dan Dryden, 1959, hlm. 154)

Jumlah tanki yang digunakan 2 buah

$$\text{Maka massa bahan tiap storage} = \frac{32844{,}766 \times 5 \text{ kg}}{2} \text{ kg} = 82111{,}915 \text{ kg}$$

a. Menghitung diameter shell

Volume ethanol pertanki = 82111,915 : (0,4536 x 49,642) = 3646,564 cuft

Safety allowance 10% (Vilbrandt, 1959, hlm. 152) maka volume tangki

= 1,1 x 3646,564 cuft = 4011,220 cuft = 30007,937 gallon

Digunakan tutup atas berbentuk ellipsoidal, dan bagian bawah datar

Tinggi dish head = 1/4 . D (Hesse, 1959, hlm.92)

Volume dish head = π . D^3 / 24 (Hesse,1959, pers. 4-12 hlm. 92)

maka volume shell = volume total tangki – (1 x π . D^3 / 24)

= 4011,220 – 1 (π . D^3 / 24)

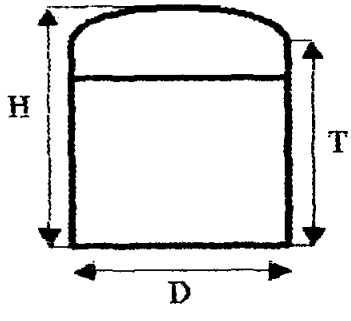
= 4011,220 – 0,13083 D^3

Volume shell = ¼ π . D^2 . T = 4011,220 – 0,13083 D^3

= 0,785 D^2 . T = 4011,220 – 0,13083 D^3

H = D – 2D (Ulrich, 1984, hlm. 248-249), ditetapkan H = 1,5 D

maka persamaan menjadi = 0,785 : D^2 x 1,25 D = 4011,220 - 0,13083 D^3



D^3 = (4011,220 / 1,11208) ft^3

= 3606,953 ft^3

D = $\sqrt[3]{3606,953}$ = 15,336 ft

= 184,032 in = 467,441 cm

Volume dish head = π . D^3 / 24 = 3,14 . $(15,336)^3$ / 24 = 471,910 ft^3

T = H – (0,25 – D)

= 1,5 D – 0,25 D = 1,25 D

Volume shell $= (\pi/4)\, D^2 \,.\, T$ = volume total – volume dish head

$= (4011{,}220 - 471{,}910)$ cuft $= 3539{,}310$ cuft

Maka tinggi silinder = T = $\dfrac{3539{,}310}{0{,}785 \times 15{,}336^2}$ ft = 19,170 ft

Tinggi dish $= (1/4)\, D$

$= \dfrac{15{,}336}{4}$ ft = 3,834 ft

Tinggi total tangki = tinggi shell + tinggi dish head

$= (19{,}170 + 3{,}834)$ ft $= 23{,}004$ ft

Menghitung tekanan tangki :

Dalam keadaan maksimum,tinggi liquid = tinggi tangki (Mc.Cabe ed.3,hlm. 248-249)

b. Menghitung tekanan design (Pd)

$$p = \frac{\rho\,(g/gc)\,h}{144}$$

$= 49{,}642 \times 1 \times 23{,}004/144 = 7{,}930$ psi

p design = 1,2 x 7,930 psi = 9,516 psi (Rase, Barrow, 1967, hlm. 208)

c. Menghitung tebal head (th)

$$th = \frac{p \,.\, D}{2 \,.\, S \,.\, e} + C$$ (Hesse, 1959, hlm. 86)

dimana :

p = internal pressure

S = maksimum stress yang diijinkan, lb/in^2

D = diameter shell

e = welded-joint efficiency

C = faktor korosi, in = 0,125 in (Perry VI,hlm. 23-26)

S = 12750 lb/in^2 (Brownell, Young, 1959, hlm. 251)

e = 0,85 (Brownell, Young, 1959, table 13.2, hlm. 259)

Sehingga :

$$t\,head = \frac{9,516 \times 184,032}{2 \times 12750 \times 0,85} + 0,125\ in = 0,206\ in \approx 4/16\ in = 0,250\ in$$

Tebal shell (t_s)

$$t_s = \frac{p \,.\, D}{2 \,.\, Se \,.\, p} + C \quad \text{(Hesse, 1959, hlm. 85)}$$

$$t_s = \frac{9,516 \times 184,032}{2 \times 12750 \times 0,85 - 9,516} + 0,125\ in = 0,207\ in$$

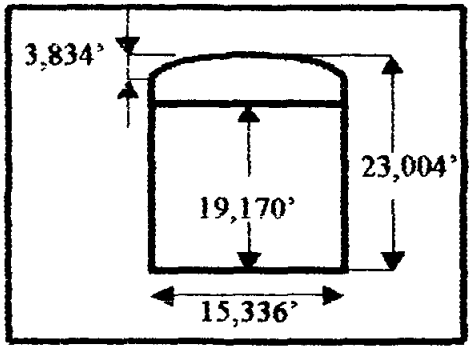
dipakai tebal shell 4/16 in = 0,250 in

01. Spesifikasi 95% Ethanol Storage (F-110)

Type : Tangki vertikal, tutup atas ellipsoidal, bawah datar.

Kapasitas : 30007,937 gallon

Dimensi : - diameter shell = 15,336 ft



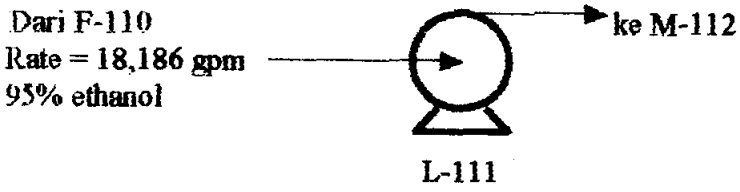
- tinggi shell = 19,170 ft
- tinggi total = 23,004 ft
- tinggi dish = 3,834 ft
- tebal shell = 4/16 in
- tebal dished = 4/16 in

Bahan konstruksi : Carbon steel

Jumlah : 2 buah

02. 95% ETHANOL PUMP (L – 111)

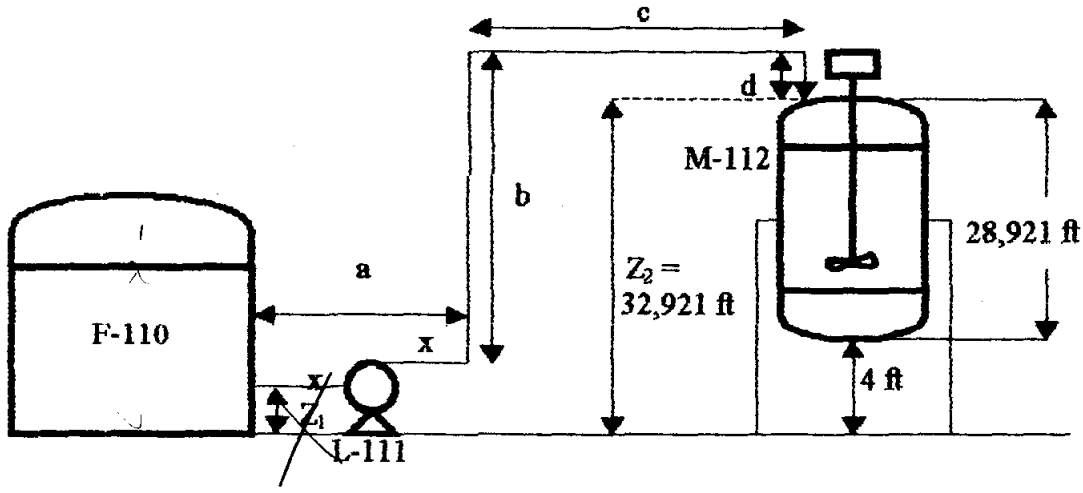
Gambar 95% ethanol pump dan aliran massa



Fungsi : Memompa ethanol 95% dari 95% Ethanol Storage (F-110).

Proses : batch

Diagram perpipaan pompa :



Data dan perkiraan (estimasi) perancangan

Perkiraan panjang pipa lurus = a + b + c + d = 110 ft

Jumlah elbow = 3 buah

Jumlah valve (x) = 2 buah

Z_1 = 1 ft ; Z_2 = 32,921 ft

Perhitungan :

ρ = 49,642 lb/cuft

$\mu \approx 1$ Cps

Kebutuhan perhari = 32844,766 kg/hari

Kebutuhan perbatch = (32844,766 : 24) kg/batch = 1368,532 kg/batch

Dipompa dengan waktu 25 menit

$$\text{Rate pemompaan (Q)} = \frac{1368,532}{0,4536 \times 49,642 \times 25} \text{ cuft/menit} = 2,431 \text{ cuft/menit}$$

$$= 18,186 \text{ gpm} = 0,041 \text{ cuft/detik}$$

Optimum inside pipe diameter sesuai Peters, 1991, hlm.498 adalah sebagai berikut :

$$\text{ID optimum} = 3,9 \,.\, (Q)^{0,45} \,.\, (\rho)^{0,13}$$

$$= 3,9\ (0,041)^{0,45} \,.\, (49,642)^{0,13} = 1,539 \text{ in}$$

Sesuai Foust, 1974, hlm.74 maka dipilih nominal pipe size = 1,5 in Sch 40

Dari Foust,1974, hlm. 742, didapat :

Pipa nominal size = 1,5 in Sch 40 :

OD = 1,90 in = 0,158 ft

ID = 1,610 in = 0,134 ft

Luas penampang = 0,014 ft^2

<u>Menghitung kecepatan aliran</u> :

Kecepatan aliran mula-mula = $V_1 = 0$

$$V_2 = \frac{0,041 \text{ ft}^3/\text{detik}}{0,014 \text{ ft}^2} = 2,929 \text{ ft/detik}$$

<u>Menghitung NRe (Renault Number)</u>

$$NRe = \frac{D \,.\, V \,.\, \rho}{\mu}$$

$$= \frac{0{,}134 \times 2{,}929 \times 49{,}642}{6{,}72 \cdot 10^{-4}} = 28994 > 2100$$

Maka aliran turbulent

Sesuai Foust, 1974, hlm. 717 maka dipilih pipa komersial steel (e = 0,00015) didapat $\in$/d = 0,0012 ; f = 0,026

Panjang pipa lurus = 110 ft, 3 buah elbow 90° dengan harga Le/D = 30, maka

Le = 3 x 30 x 0,134 = 12,06 ft

Bila digunakan 2 buah gate valve dengan harga Le/D = 35 pada keadaan ¾ terbuka maka :

Le = 2 x 35 x 0,134 ft = 9,38 ft

Total panjang equivalent = (110 + 12,06 + 9,38) ft = 131,440 ft

Tinggi inlet = Z_1 = 1,0 ft dan tinggi outlet = Z_2 = 32,921 ft maka ΔZ = 31,921 ft

Tekanan di alat 1 = P_1 = 1 atm ; tekanan di alat 2 = P_2 = 1 atm maka ΔP = 0

Untuk perhitungan friksi digunakan rumus-rumus dari Peters,1991, hlm.483

a/. Friksi karena gesekan dalam pipa : *(Peters hal 483)*

$$F = \frac{2 f V^2 L}{gc\ D}$$

$$= \frac{2 \times 0{,}026 \times (2{,}929)^2 \times 131{,}440}{32{,}17 \times 0{,}134} = 13{,}602 \text{ ft}$$

b/. Friksi karena kontraksi dari tangki ke pipa

$$Fe = \frac{Kc\ V^2}{2.\alpha\ gc}$$

Karena aliran turbulent, maka α = 1

(Sesuai Peters,1991, hlm. 484-485)

$$= \frac{0{,}5 \times (2{,}929)^2}{2 \times 1 \times 32{,}17} = 0{,}067 \text{ ft}$$

c/. Friksi karena perluasan (enlargement) :

$$Fc = \frac{(V_1 - V_2)^2}{2\,\alpha\,.\,gc} \qquad \text{turbulent } \alpha = 1;\ V_1 = 2{,}929\ ;\ V_2 = 0$$

$$= \frac{(2{,}929 - 0)^2}{2 \times 1 \times 32{,}17} = 0{,}133 \text{ ft}$$

$\Sigma F = 13{,}602 + 0{,}067 + 0{,}133 = 13{,}802$ ft

Sesuai rumus dari Peters,1991, hlm. 487 didapat :

$$Z_2 - Z_1 + \frac{v_2^2}{2\alpha\, gc} - \frac{v_1^2}{2\alpha\, gc} + p_2v_2 - p_1v_1 + \Sigma F = Wo$$

$p_1 = p_2 =$ tekanan atmosfir, $v_1 = v_2$ (liquid dianggap noncompressible fluid) , maka

$p_2v_2 - p_1v_1 = 0$, persamaan menjadi :

$$Z_2 - Z_1 + \frac{v_2^2}{2\alpha\, gc} - \frac{v_1^2}{2\alpha\, gc} = Wo - \Sigma F$$

$V_2 = 2{,}929$ ft/detik ; $V_1 = 0$; $\Delta V = 2{,}929$ ft/detik

$$1 \times 31{,}921 + \frac{(2{,}929)^2}{2 \times 32{,}17} + 13{,}802 = dWo$$

$dWo = 45{,}856$ ft $= H$

Sesuai dari Perry edisi V, hlm. 6-3 didapat rumus sebagai berikut :

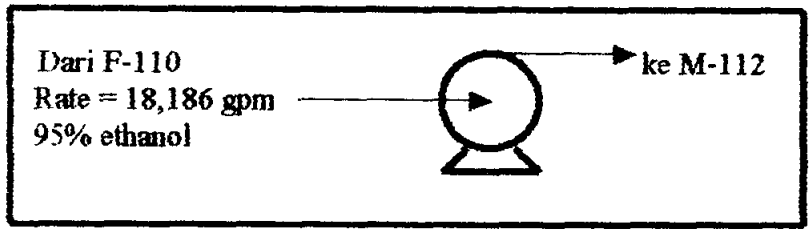
$$HP = \frac{H \times sg \times gpm}{3960}$$

Dari Peters, 1991, hlm. 520, efisiensi pompa dengan rate 18,186 gpm adalah 25 %, maka tenaga penggerak yang digunakan adalah :

$$HP = \frac{45,856 \times 0,7955 \times 18,186}{3960 \times 0,25} = 0,670 \text{ HP}$$

Menggunakan motor penggerak = 0,75 HP

02. Spesifikasi 95% Ethanol Pump (L – 111)



Diameter pipa : 1,5 in Sch 40

Rate : 18,186 gpm

Head : 45,856 lbf.ft / lbm

Power : 0,75 HP

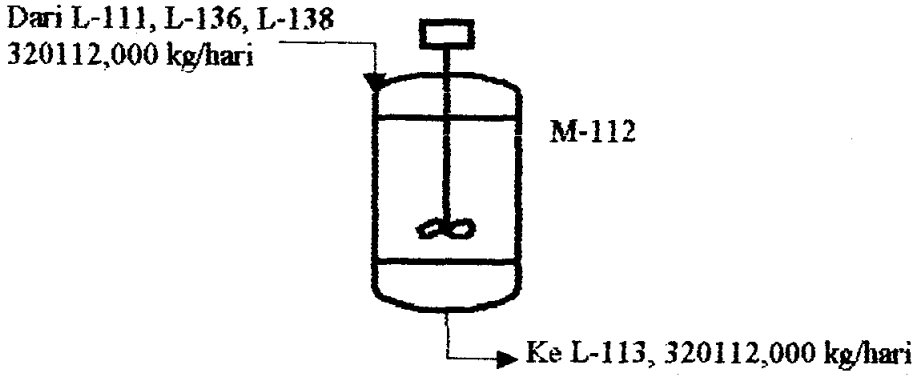
Jenis : Centrifugal

Bahan : Carbon steel

Jumlah : 1 buah

03. MATERIAL MIXING TANK (M – 112)

Gambar material mixing tank dan aliran massa



Fungsi : Untuk mencampur etanol 95%,waste dan Acetic Acid 80% hingga terbentuk campuran 10,5% etanol, 1 % Acetic Acid dan 88,5% H_2O.

Type : Silinder tegak, tutup atas dan tutup bawah berbentuk dish dilengkapi pengaduk

Proses : batch

Bahan masuk = 320112,000 kg/hari

Perhitungan :

$$\frac{1}{\rho \text{ camp}} = \frac{0,105}{0,78075} + \frac{0,01}{1,0380} + \frac{0,885}{1} = 1,0291 \text{ kg/liter}$$

ρ camp = 0,9717 kg/liter = 60,634 lb/cuft

Waktu pengadukan ditetapkan 60 detik (Ulrich, 1984, hlm. 177)

Ditetapkan 1 batch waktu operasi 1 jam

Jumlah batch = 24/1 batch = 24 batch/hari

-waktu pengisian = 25 menit

-waktu pengosongan = 25 menit

-waktu pencampuran = 1 menit

-allowance = 9 menit

a. Menghitung diameter shell

$$\text{Volume liquid perbatch} = \frac{320112{,}000}{24 \times 0{,}4536 \times 60{,}634} \text{ cuft}$$

$$= 484{,}955 \text{ cuft} = 3627{,}948 \text{ gallon}$$

Safety allowance 20 %

Volume tangki = 1,2 x 3627,948 cuft = 4353,538 cuft = 32568,818 gallon

Digunakan tutup atas dan bawah berbentuk ellipsoidal.

Tinggi liquid di dish = tinggi dish = 1/4 . D (Hesse, hlm.92)

Volume liquid di dish = $\pi . D^3 / 24$ (Hesse pers. 4-12 hlm. 92)

maka volume shell = volume total tangki – $2 \times \pi . D^3 / 24$

$= 4353{,}538 - 2 (\pi . D^3 / 24)$

$= 4353{,}538 - 0{,}262\ D^3$

ditetapkan : H = 1,5D (Ulrich, 1984, hlm. 248)

H = tinggi silinder

Volume shell $= \frac{1}{4} \pi . D^2 . H = 4353{,}538 - 0{,}262\ D^3$

$= 0{,}785\ D^2 . 1{,}5D = 4353{,}538 - 0{,}262\ D^3$

maka persamaan menjadi = $1{,}1775\ D^3 = 4353{,}538 - 0{,}262\ D^3$

$4353{,}538 = 1{,}4395\ D^3$

$D^3 = (4353{,}538 / 1{,}4395)\ ft^3 = 3024{,}340\ ft^3$

$D = \sqrt[3]{3024{,}340} = 14{,}461 \text{ ft} = 173{,}532 \text{ in}$

Volume dish bottom = volume dish head

$= \pi \cdot D^3 / 24 = 3{,}14 \cdot (14{,}461)^3 / 24 = 395{,}684\ ft^3$

Tinggi silinder = 1,5 x 14,461 ft = 21,691 ft

Tinggi total tangki = tinggi shell + 2 . tinggi dish

= 21,691 + 2 . (1/4 . 14,461) ft = 28,921 ft

Menghitung tekanan tangki :

Dalam keadaan maksimum,tinggi liquid =tinggi tangki (Mc.Cabe ed.III hlm.248-249)

b. Menghitung tekanan design (Pd)

$$P = \frac{\rho\,(g/gc)\,h}{144}$$

= 60,634 x 1 x 28,921/144 = 12,178 psi

P design = 1,2 x 12,178 psi = 14,614 psi

c. Menghitung tebal shell (ts)

$$ts = \frac{P \times D}{2\,fE - P} + C$$

dimana :

P = internal pressure

f = maksimum stress yang diijinkan, lb/in^2

D = diameter shell

E = welded-joint efficiency

C = faktor korosi, in

f = 12750 lb/in^2 (Brownell & Young, hal 251)

C = 0,125 inchi

E = 0,85 (B & Y, table 13.2, hal 259)

Sehingga :

$$t\ shell = \frac{14,614 \times 173,532}{2 \times [(12750 \times 0,85) - (14,614)]} + 0,125\ in = 0,241\ in \approx 0,250\ in$$

Lapis Stainless steel 316 = 0,125 in

d. Menghitung tebal dish (ts)

$$ts = \frac{P \times D}{2\,Se - P} + C \qquad \text{(Hesse, 1959, hlm.85)}$$

$$t\ shell = \frac{14,614 \times 173,532}{2 \times 12750 \times 0,85} + 0,125\ in$$

= 0,242 in ≈ 4/16 in = 0,250 in, lapis stainless steel 316 = 0,125 in

e. Perhitungan power pengaduk

Dipakai impeller jenis turbin dengan 6 buah flat blade.Menurut Mc. Cabe edisi 4, figure 9-9) :

Dt/Da = 3 ; E = Da

Da = 1/3 x 14,461 ft = 4,820 ft = 1,469 meter

μ = 1 Cps = 0,000672 lb/ft.s

ρ = 60,634 lb/cuft

Digunakan kecepatan putar = 45 rpm = 0,75 rps

$$Nre = \frac{\rho \times D^2 \times N}{\mu} = \frac{60,634 \times (4,820)^2 \times 0,75}{0,000672} = 1572180$$

Dari grafik 1,2 Frank, hlm. 11, untuk turbin flat six bladedidapat harga Np = 1,3

Sehingga

$$P = \frac{N\rho \cdot \rho \cdot N^3 \cdot D^5}{550 \cdot gc}$$

$$= \frac{1{,}3 \times 60{,}634 \times (0{,}75)^3 \times (4{,}820)^5}{550 \times 32{,}2} = 4{,}885 \text{ Hp}$$

Untuk motor 4,9 Hp, effisiensi motor = 85% (Vilbrandt dan Dryden,1959, hlm.149)

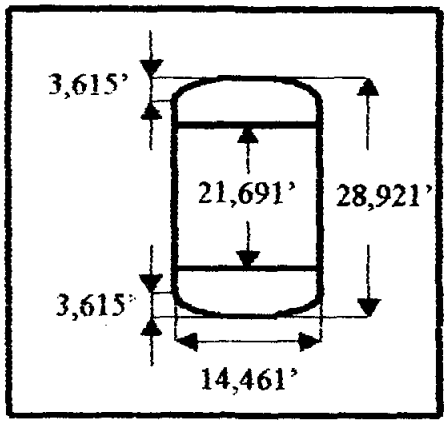
$$\text{Power motor} = \frac{4{,}885}{0{,}85} = 5{,}75 \text{ Hp, menggunakan 6 Hp}$$

03. Spesifikasi Material Mixing Tank (M-112)

Type : Tangki vertikal dengan tutup atas dan bawah berbentuk dish dilengkapi pengaduk.

Kapasitas : 32568,818 gallon

Dimensi : - diameter shell = 14,461 ft



- tinggi shell = 21,691 ft
- tinggi total = 28,921 ft
- tinggi dished = 3,615 ft
- tebal shell = 4/16 in
- tebal dished = 4/16 in

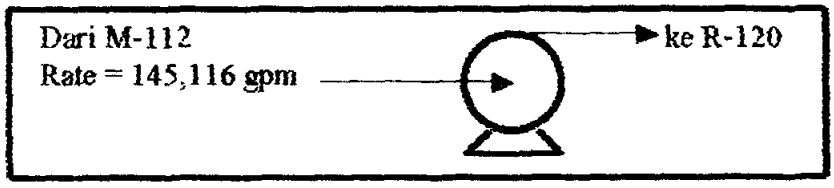
Tenaga penggerak pengaduk : 6 Hp

Bahan konstruksi : Carbon steel, lapis SS. 316

Jumlah : 1 buah

04. MATERIAL MIXED PUMP (L – 113)

Fungsi : Memompa larutan campuran ethanol 10,5%, 1% acetic acid dan H_2O dari Material Mixing Tank (M-112).



Diameter pipa : 4,0 in Sch 40

Rate : 145,116 gpm

Head : 67,259 lbf.ft / lbm

Power : 5,0 HP

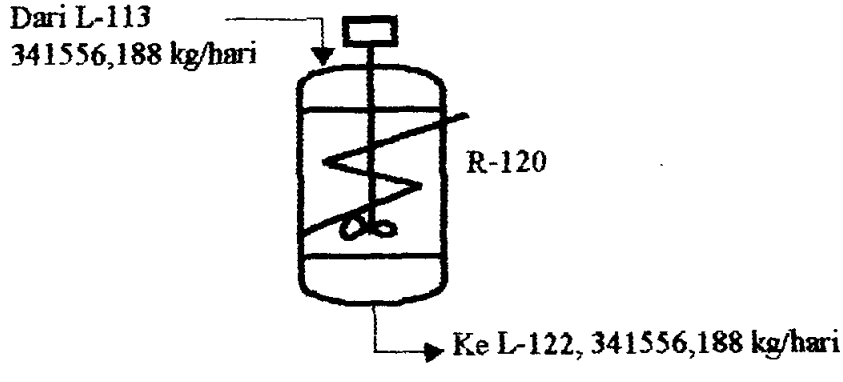
Jenis : Centrifugal

Bahan : Carbon steel, lapis SS. 316

Jumlah : 1 buah

05. FERMENTOR (R – 120)

Gambar fermentor dan aliran massa



Fungsi : Tempat terjadinya fermentasi alcohol menjadi Acetic Acid dengan bantuan bacterium acetic.

Type : Silinder tegak, tutup atas dan tutup bawah berbentuk dish.

Proses : batch

Jumlah bahan liquid = 341556,188 kg/hari

$$\frac{1}{\rho \text{ camp}} = \frac{0,1265}{1,0380} + \frac{0,0086}{0,78075} + \frac{0,8649}{1}$$

$$= 0,99779 \text{ lt/kg}$$

$$\rho \text{ camp} = \frac{1}{0,99779} \text{ kg/lt} = 1,0022 \text{ kg/lt} = 62,537 \text{ lb/cuft}$$

Perhitungan :

Waktu tinggal = 10 hari

a. Menghitung diameter shell

Volume liquid perbatch = 341556,188 : (0,4536 x 62,537)

= 12040,709 cuft = 90076,544 gallon

Safety allowance 20 %

Volume tangki = 1,2 x 12040,709 cuft = 14448,851 cuft = 108091,853 gallon

Digunakan tutup atas dan bawah berbentuk ellipsoidal.

Tinggi liquid di dish = tinggi dish = 1/4 . D (Hesse, hlm.92)

Volume liquid di dish = $\pi . D^3 / 24$ (Hesse pers. 4-12 hlm. 92)

maka volume shell = volume total tangki – 2 x $\pi . D^3 / 24$

= 14448,851 – 2 ($\pi . D^3 / 24$)

= 14448,851 – 0,262 D^3

ditetapkan tinggi total = 2 D (Shreve,1956, hlm. 690)

H = tinggi silinder = 2D – tinggi tutup atas + bawah

= 2D – 0,5 D = 1,5 D

Volume shell $= \frac{1}{4} \pi . D^2 . H = 14448,851 - 0,262\ D^3$

$= 0,785\ D^2 . 1,5\ D = 14448,851 - 0,262\ D^3$

maka persamaan menjadi = $1,1775\ D^3 = 14448,851 - 0,262\ D^3$

$14448,851 = 0,9155\ D^3$

$D^3 = (14448,851 / 0,9155)\ ft^3 = 15782,470\ ft^3$

$D = \sqrt[3]{15782,470} = 25,084\ ft = 301,008\ in$

Volume dish bottom = volume dish head

$= \pi . D^3 / 24 = 3,14 . (25,084)^3 / 24 = 2064,873\ ft^3$

Tinggi silinder = 1,5 x 25,084 ft = 37,626 ft

Tinggi total tangki = tinggi shell + 2 . tinggi dish

= 37,626 + 2 . (1/4 . 25,084) ft = 50,168 ft

Menghitung tekanan tangki :

Dalam keadaan maksimum,tinggi liquid=tinggi tangki (Mc.Cabe ed.III hlm.248-249)

b. Menghitung tekanan design (Pd)

$$P = \frac{\rho\ (g/gc)\ h}{144}$$

= 62,537 x 1 x 50,168/144 = 21,787 psi

P design = 1,2 x 21,787 psi = 26,144 psi

c. Menghitung dish (td)

$$td = \frac{P \times D}{2fE - P} + C$$

dimana :

P = internal pressure

f = maksimum stress yang diijinkan, lb/in^2

D = diameter shell

E = welded-joint efficiency

C = faktor korosi, in

f = 12750 lb/in^2 (Brownell & Young, hal 251)

C = 0,125 inchi

E = 0,85 (B & Y, table 13.2, hal 259)

Sehingga :

$$t\ dish = \frac{26,144 \times 301,008}{2 \times [(12750 \times 0,85) - (26,144)]} + 0,125\ in$$

= 0,488 in ≈ 8/16 in, lapis stainless steel 316 = 0,125 in

d. Menghitung tebal dish (ts)

$$ts = \frac{P \times D}{2Se} + C$$ (Hesse, 1959, hlm.85)

$$t\ shell = \frac{26,144 \times 301,008}{2 \times 12750 \times 0,85} + 0,125\ in = 0,488\ in \approx 8/16\ in$$

Lapis stainless steel 316 = 0,125 in

e. Perhitungan power pengaduk

Dipakai impeller jenis turbin dengan 6 buah flat blade.Menurut Mc. Cabe edisi 4, figure 9-9) :

Dt/Da = 3 ; E = Da

Da = 1/3 x 25,084 ft = 8,361 ft = 2,548 meter

μ = 2 Cps = 0,001344 lb/ft.s

ρ = 62,537 lb/cuft

Digunakan kecepatan putar = 25 rpm = 0,417 rps

$$Nre = \frac{\rho \times D^2 \times N}{\mu} = \frac{62,537 \times (2,548)^2 \times 0,417}{0,001344} = 125972$$

Dari grafik 1,2 Frank, hlm. 11, untuk turbin flat six bladedidapat harga Np = 1,3

Sehingga

$$P = \frac{Np \cdot \rho \cdot N^3 \cdot D^5}{550 \cdot gc}$$

$$= \frac{1,3 \times 62,537 \times (0,417)^3 \times (8,361)^5}{550 \times 32,2} = 13,601 \text{ Hp}$$

Power motor = (1,1 x 13,601 + 0,5) Hp = 15,461 Hp

Menggunakan tenaga penggerak = 16 Hp

Perhitungan didasarkan Kern hlm. 718 – 720 dan dari Perry edisi 3 hlm. 474

$$\left[\frac{H\ D}{k}\right]\left[\frac{C\mu}{k}\right]^{-1/3}\left[\frac{\mu s}{k}\right]^{0,14} = a\left[\frac{L\rho^2 N\rho}{\mu}\right]^{n}$$

(Dari Perry edisi 3, pers 44a)

Untuk coil a = 0,87, n = 0,62 persamaan disesuaikan dengan Kern hlm. 718 menjadi :

$$\frac{hi \cdot D}{k} = 0{,}87 \left[\frac{L^2 N \rho}{\mu}\right]^{0,62} \left[\frac{C\mu}{k}\right]^{+1/3} \left[\frac{\mu k}{\mu w}\right]^{-0,14}$$

Panjang lengan pengaduk = L = 8,361 ft

ρ = 97,078 lb/cuft

Putaran pengaduk = N = 25 x 60 = 1500 rev/hr

Viscositas bahan = μ = 2,5 x 2,42 lb/ft hr = 6,05 lb/ft.hr

Viscositas H_2O = μ = 0,8 x 2,42 lb/ft.hr = 1,936 lb/ft.hr

Capasitas panas bahan = C = 0,7 Btu/lb°F

$$Rej = \frac{L^2 \cdot \rho \cdot N}{\mu}$$

$$= \frac{(8{,}361)^2 (62{,}537) (1500)}{6{,}05} = 1083900$$

Dari Kern fig 20.2, NRe = 779863 untuk coil diperoleh harga j ≈ 2500

$$J = 2500 = \frac{h D}{k} \left[\frac{C\mu}{k}\right]^{1/3} \left[\frac{\mu}{\mu w}\right]^{-0,14}$$

$$\left[\frac{\mu}{\mu w}\right]^{-0,14} = \left[\frac{6{,}05}{1{,}936}\right]^{-0,14} = 1{,}173$$

Diameter tangki = D = 25,084 ft

$$\left[\frac{C\mu}{k}\right]^{-1/3} = \left[\frac{0{,}7 \cdot 6{,}05}{0{,}2}\right]^{-1/3} = 0{,}361$$

$$J = 2500 = \frac{h \,.\, 25{,}084}{0{,}2} (0{,}361)\,(1{,}173)$$

$$2500 = 53{,}109\ hi$$

$$hi = 47{,}073$$

$$Uc = \frac{hi \times hoi}{hi + hoi}$$

hoi = water side coefficient dari Mc Adam hlm. 187 ditetapkan 1800

$$Uc = \frac{47{,}073 \times 1800}{47{,}073 + 1800} = \frac{84731{,}4}{1847{,}073} = 45{,}873$$

$$Rd = 0{,}005 \qquad hd = \frac{1}{Rd} = \frac{1}{0{,}005} = 200$$

$$\frac{1}{U_D} = \frac{1}{Uc} + Rd \text{ atau}$$

$$U_D = \frac{Uc \,.\, hd}{Uc + hd}$$

$$= \frac{45{,}873 \times 200}{45{,}873 + 200} = \frac{9174{,}6}{245{,}873} = 37{,}314$$

Jadi overall coefficient heat transfer = 37,314 Btu/hr.ft^2.°F

$$\ln \frac{T_1 - t_1}{T_1 - t_2} = \frac{U\,A\,\theta}{M.C} \qquad \text{(Kern, 18.5,hlm. 627)}$$

Dimana :

C = kapasitas panas dari bahan yang dipanasi

θ = waktu,jam

A = luas perpindahan panas

T_1 = suhu bahan mula-mula

t_1 = suhu air pendingin mula-mula (masuk)

t_2 = suhu air pendingin keluar

$$ln = \frac{124,8 - 86}{124,8 - 113} = \frac{37,314 \cdot A \cdot 24}{47748,2 \cdot 0,7}$$

$$= \frac{38,8}{11,8} = 0,018755\ A$$

$$= 3,288136$$

$$A = 175,320\ ft^2$$

f. Penentuan diameter pipa (coil) air pendingin

Rate air pendingin = 5188811,04413 kg/hari = 216200,460 kg/jam

= 60,056 kg/detik = 0,2121 cuft/detik

ID optimal $= 3,9\ (Q)^{0,45}\ (\rho)^{0,13}$

$= 3,9\ (2,121)^{0,45}\ (62,4)^{0,13}$

= 3,3 in digunakan pipa 3,5 in

g. Panjang coil pendingin

Dari Foust hlm. 724

Nominal pipe size = 3,5 in schedule No 40

Outside diameter pipa 3,5 in = 4,0 in

Inside diameter pipa 3,5 in = 3,548 in

$$\text{Diameter rata-rata} = \frac{4{,}0 + 3{,}548}{2} \text{ in} = 3{,}774 \text{ in}$$

Keliling pipa 3,5 in $= \pi \times 3{,}774 = 11{,}850$ in

Luas per ft panjang $= 11{,}850 \times 12 \text{ in}^2 = 142{,}2 \text{ in}^2$

$= 0{,}9875 \text{ ft}^2$

$$\text{Panjang coil yang diperlukan} = \frac{A}{\text{luas per panjang coil}} = \frac{175{,}320}{0{,}9875} \text{ ft}$$

$= 177{,}539$ ft

h. Jumlah lingkar coil pendingin

Diameter dalam tanki reactor $= 25{,}084$ ft

Diameter pengaduk $= 8{,}361$ ft

Coil diletakkan ditengah-tengah antara dinding tanki dan kipas (blade) pengaduk

$$\text{Jarak coil dari dinding tanki} = \frac{25{,}084 - 8{,}361}{2} \text{ ft} = 8{,}361 \text{ ft}$$

Diameter coil (center) $= (25{,}084 - 8{,}361)$ ft $= 16{,}723$ ft

$$\text{Jumlah lingkaran coil} = \frac{\text{total panjang coil} - (2 \times \text{jarak coil dengan dinding shell})}{\text{keliling coil}}$$

$$= \frac{177{,}539 - (2 \times 8{,}361)}{3{,}14 \times 16{,}723} \text{ buah}$$

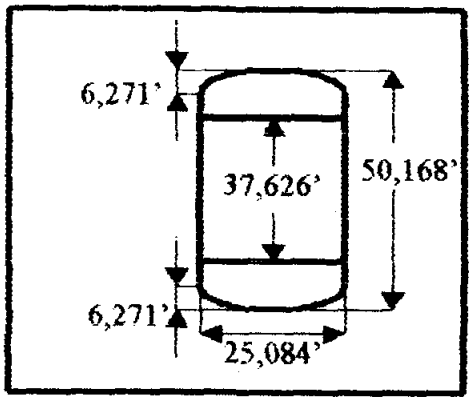
$= 3{,}06$ buah ≈ 4 buah

05. Spesifikasi Fermentor (R-120)

Type : Tangki vertikal dengan tutup atas dan bawah berbentuk dish.

Kapasitas : 108091,853 gallon

Dimensi



: - diameter shell = 25,084 ft

- tinggi silinder = 37,626 ft
- tinggi total = 50,168 ft
- tinggi dish = 6,271 ft
- tebal shell = 8/16 in
- tebal dished = 8/16 in

Tenaga penggerak pengaduk : 16 Hp

Bahan konstruksi : Carbon steel lapis SS. 316

Luas pemindah panas : 175,320 ft^2

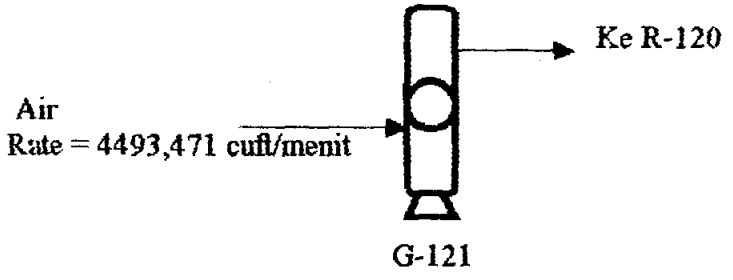
Panjang coil : 177,539 ft

Jumlah lilitan : 4 buah

Jumlah : 10 buah

06. AIR BLOWER (G – 121)

Gambar air blower dan aliran massa



Fungsi : menghembuskan udara kedalam Fermentor (R-120).

Kapasitas udara = 199584,000 kg/hari = 8316,000 kg/jam

= 18333,333 lb/jam = 305,556 lb/menit

Suhu = 30°C = 86°F = 546°R

$$\frac{P.V}{P_s.V_s} = \frac{n.T}{n_s.T_s}$$ (Felder, hlm. 171)

1 lbmol gas ideal pada suhu 492°R, 1 atm mempunyai volume 359 ft^3 maka,

$$\text{Density udara} = \frac{29}{359} \times \frac{14,7}{14,7} \times \frac{492}{546} \text{ lb/cuft} = 0,068 \text{ lb/cuft}$$

$$\text{Rate udara} = \frac{305,556 \text{ lb/menit}}{0,068 \text{ lb/cuft}} = 4493,471 \text{ cuft/menit}$$

$P_2 - P_1 \approx$ maksimal 1,5

$$\text{Power blower} = \frac{144 \times Q (P_2 - P_1)}{33000}$$ (Perry V, hal 6 – 20)

$$= \frac{144 \times 4493,471 \times 1,5}{33000} = 29,412 \text{ Hp}$$

Untuk power 29,412 Hp, efficiency motor 3 phase = 88%

$$\text{Power sesungguhnya yang digunakan} = \frac{29,412}{0,88} = 33,423 \text{ Hp} \approx 35 \text{ Hp}$$

06. Spesifikasi Air Blower (G – 121)

Rate : 4493,471 cuft/menit

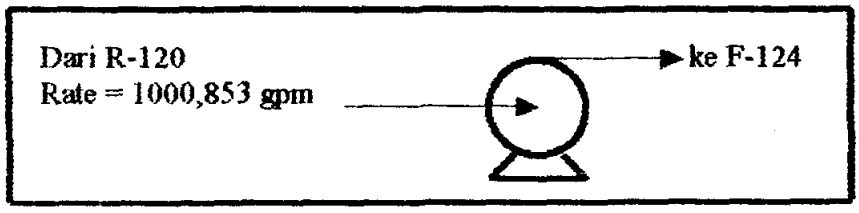
Power : 35 Hp

Bahan : Carbon steel

Jumlah : 1 buah

07. RAW ACETIC ACID PUMP I (L – 122)

Fungsi : Memompa larutan hasil fermentasi dari Fermentor (R-120) ke Raw Acetic Acid Storage (F-124).



Diameter pipa : 10 in Sch 40

Rate : 1000,853 gpm

Head : 33,027 lbf.ft / lbm

Power : 15,0 HP

Jenis : Centrifugal

Bahan : Carbon steel, lapis SS. 316

Jumlah : 1 buah

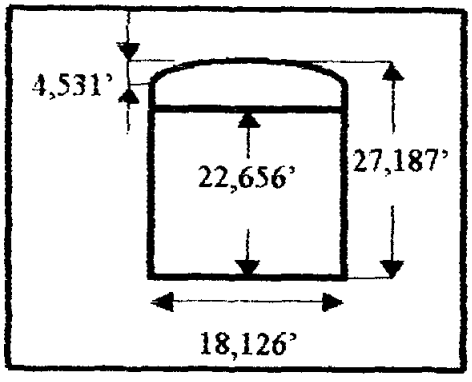
08. RAW ACETIC ACID STORAGE (F – 123)

Fungsi : Untuk menampung Raw Acetic Acid dari Fermentor (R-120).

Type : Silinder tegak, tutup atas berbentuk ellipsoidal, bagian bawah datar.

Kapasitas : 49541,898 gallon

Dimensi :



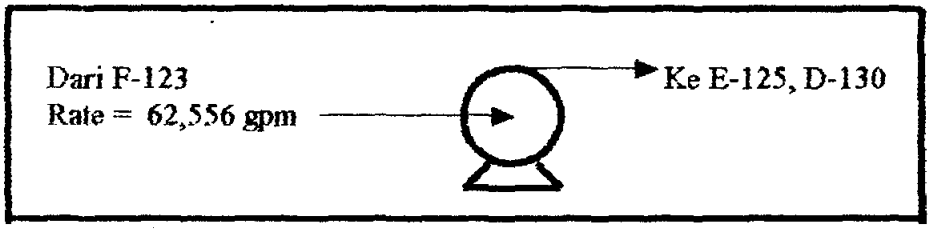
- diameter shell = 18,126 ft
- tinggi shell = 22,056 ft
- tinggi total = 27,187 ft
- tinggi dished = 4,531 ft ft
- tebal shell = 5/16 in
- tebal dished = 5/16 in

Bahan konstruksi : Carbon steel, lapis SS. 316

Jumlah : 2 buah

09. RAW ACETIC ACID PUMP II (L – 124)

Fungsi : Memompa Raw Acetic Acid dari Raw Acetic Acid Storage (F-123) ke Heater (E-125) dan Distilator Column (D-130).



Diameter pipa : 3,0 in Sch 40

Rate : 62,556 gpm

Head : 95,511 lbf.ft / lbm

Power : 3,0 HP

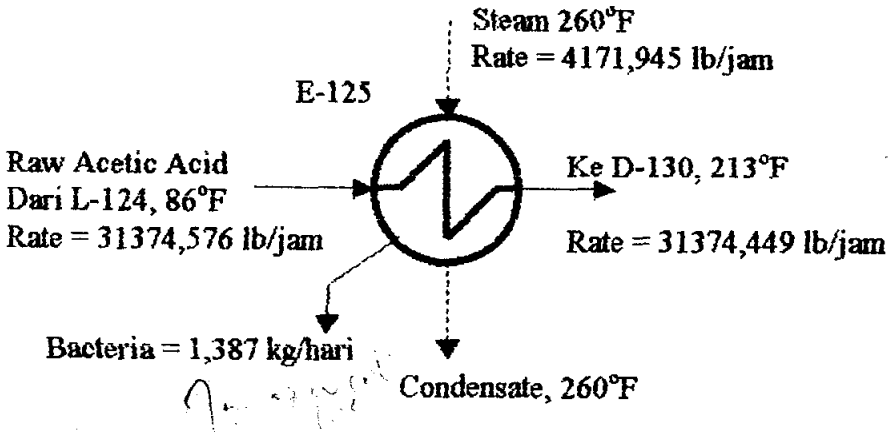
Jenis : Centrifugal

Bahan : Carbon steel, lapis SS. 316

Jumlah : 1 buah

10. HEATER (E – 125)

Gambar heater dan aliran massa



Fungsi : Menaikkan suhu Raw Acetic Acid dari 30°C menjadi 100,5°C

Type : Shell-tube kettle reboiler

Perhitungan :

Suhu bahan masuk = 30°C = 86°F

Suhu bahan keluar = 100,5°C = 213°F

Dari perhitungan neraca panas Heater

Q_R = 23685204,512 kkal/hari = 93988906,7936 Btu/hari

= 3916204,450 Btu/jam

Media pemanas dipakai steam :

T = 260°F

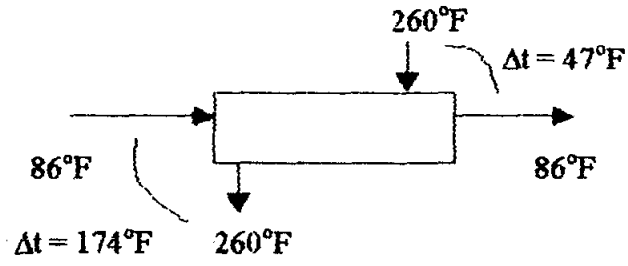
λ = 938,7 Btu/lb

1. Jumlah steam = 100126,671773 lb/hari

= 4171,945 lb/jam

2. L M T D

Ft = 1,0 (salah satu fluida suhunya konstan)



$$LMTD = \frac{174 + 47}{2} = 110,5\ ^\circ F$$

3. Suhu kalorik

$$Tc = \frac{260 + 260}{2} = 260\ ^\circ F$$

$$tc = \frac{86 + 213}{2} = 149,5\ ^\circ F$$

Asumsi : $U_D = 90$ Btu/j $(ft^2)^\circ F$

$$Q = U_D \cdot A \cdot \Delta t$$

$$A = \frac{3916204,450}{90\ (110,5)} = 393,786\ ft^2$$

Dipilih ukuran pipa :

¾ in OD, 16 BWG, 15/16" triangular pitch, L = 5,85 ft

$$Nt = \frac{A}{\pi \times Do \times L} \longrightarrow a'' = 0,1963\ ft^2 \text{ (tab 10)}$$

$$= \frac{393,786}{(0,1963)\ 5,85} = 342,91$$

Dari tabel 9, diperoleh :

ID shell = 21,25 in

Nt = 342

Passes = 2

U_D koreksi :

A = Nt x a" x L

= 342 x 0,1963 x 5,85 = 392,737 ft^2

Q = U_D x A x Δt

$$U_D = \frac{3916204,450}{392,737\ (110,5)} = 90,240 \approx 90\ Btu/j\ (ft^2)°F$$

Tube side : fluida panas (steam)	Shell side : fluida dingin
4. Flow area at = 0,302 in^2 (tabel 10, Kern) $at = \frac{Nt \,.\, a\,t}{144\ n}$ $= \frac{342\ (0,302)}{144\ (2)} = 0,359\ ft^2$ 5. Mass velocity $Gt = \frac{W}{At}$ $= \frac{4171,945}{0,359} = 11621,017\ lb/j(ft^2)$ 6. Pada Tc = 260°F μ = 0,018 cp (Kern,hlm. 824,825) = 0,0436 lb/j (ft^2)	

D = 0,620 in = 0,0517 ft

(Kern,hlm.844)

$$Ret = \frac{D \times Gt}{\mu}$$

$$= \frac{0,0517\ (11621,017)}{0,0436}$$

= 13780

7. hio = 1500 Btu/j(ft^2)°F

8. Asumsi

hio = 1000 Btu/j (ft^2)°F

9. $$tw = tc + \frac{hio}{hio + ho}(T_c - t_c)$$

$$= 149,5 + \frac{1500}{1500 + 1000}(260\text{-}149,5)$$

= 215,8

Δtw = tw – tc

= 215,8 – 149,5 = 66,3

Dari Kern,hlm.474 fig 15-11, hv = 1000

Jadi asumsi ho = 1000 Btu/j ft^2°F

sudah benar

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

$$= \frac{1500 \times 1000}{1500 + 1000} = 600 \text{ Btu/j } (ft^2)°F$$

11. Check Q/A

$$\frac{Q}{A} = \frac{3916204,450}{392,737} = 9971,570 \text{ Btu/j } (ft^2)°F < 20000 \text{ Btu/j } (ft^2)°F$$

12. $$Rd = \frac{Uc - U_D}{Uc \times U_D}$$

$$= \frac{600 - 90}{600 \times 90} = 0,009 \text{ j } (ft^2)°F > 0,002 \text{ (memenuhi)}$$

Pressure Drop :

1. Ret = 13780

f = 0,00023 (fig 28, Kern hlm. 836)

Dari M.Cabe, 1974, hlm. 915 steam 260°F, spesifik volume = 11,763 ft^3/lb

$$S = \frac{1}{11,763} = 0,085 \text{ lb/ft}^3$$

2. $$\Delta Pt = \frac{1}{2} \frac{f\ Gt^2\ L\ n}{5,22\ 10^{10}\ D\ S}$$

$$= \frac{1}{2} \frac{0,00023\ (11621,017)^2\ (5,85)\ (2)}{5,22\ 10^{10}\ (0,00517)\ 0,085} = 0,016 \text{ psi}$$

Gt = 11621,017

$V^2/2g$ = 0,001 (Kern, fig. 27, hlm. 837)

$$\Delta P_r = \frac{4 \times 2}{0,085} \times 0,01 = 0,094 \text{ psi}$$

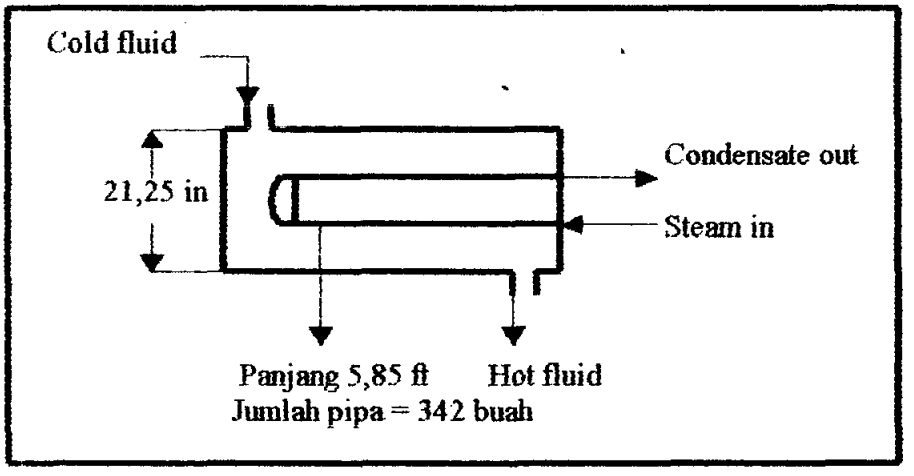
$\Delta P_T = \Delta P_T + \Delta P_r$

$= (0,016 + 0,094)$ psi $= 0,11$ psi

Ringkasan

R_d dihitung = 0,009	R_d ketentuan minimal = 0,002
ΔP_T dihitung = 0,110 psi	ΔP_T ketentuan maksimum = 10 psi
U_C = 600 Btu/hr ft^2°F	
U_D = 90 Btu/hr ft^2°F	

10. Spesifikasi Heater (E-125)



Type = Shell-tube kettle reboiler

Kapasitas panas yang diberikan = 3916204,450 Btu/jam

Luas pemindah panas = 392,737 ft^2

Panjang pipa H.E = 5,85 ft

U_D koreksi = 90,240 Btu/j (ft^2°F)

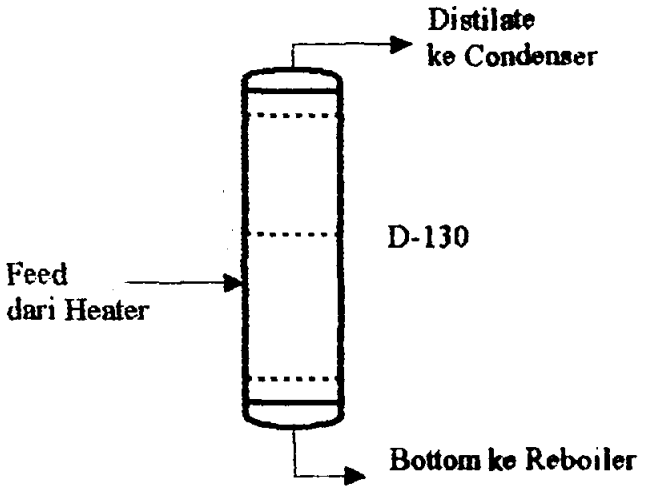
ΔP_T = 0,11 psi

Bahan konstruksi = carbon steel, lapis SS. 316

Jumlah = 1 buah

11. DISTILATOR COLUMN (D – 130)

Gambar distilator column dan aliran massa



Fungsi : Untuk memisahkan Acetic Acid dari campuran larutan C_2H_5OH dan H_2O.

Type : Plate Kolom

Perhitungan :

Beban kolom :

F (feed) = 341554,801 kg/hari

= 14231,450 kg/jam = 716,485 kgmol/jam

Produk atas (D) = 15893,858 kgmol/hari = 662,244 kmol/jam

Produk bawah (B) = 1320,034 kgmol/hari = 55,001 kmol/jam

Rop = 11,8488

q = 1 (liquida jenuh)

Dengan anggapan equimollal overflow, maka :

L = R d = 11,8488 x 662,244 kgmol/jam = 7846,7967 kmol/jam

V = (R + 1) D = 662,244 (11,8488 + 1) = 8509,0407 kmol/jam

$\overline{L}$ = q F + L = (1 x 716,485) + 7846,7967 = 8563,2817 kmol/jam

$\overline{V}$ = F (q – 1) + V= 716,485 (1 – 1) + 8509,0407 kmol/jam = 8509,0407 kgmol/jam

Kondisi operasi :

Tekanan operasi = 1 atm = 760 mmHg

Suhu operasi = 100,5°C

Menghitung BM rata-rata

Bagian Enriching (distillate product)

Atas : BM liquid = 287553,401 : 15893,858 = 18,092

BM uap = BM liquid

= 18,092

Bawah (feed)

BM liquid = (0,04187219 x 60) + (0,00372326 x 46) + (0,9715838 x 18)

(X_i) = 2,512 + 0,171 + 17,489 = 20,172

BM uap = (0,02286442 x 60) + (0,008622286 x 46) + (0,9715838 x 18)

$Y_i = k_i.x_i$ (Bubble point feed) = 1,372 + 0,397 + 17,489 = 19,258

Bagian Exhausting

Atas : BM liquid = 20,172

BM uap = 19,258

Bawah BM liquid = (0,54545455 x 60) + (0,02272727 x 46) + (0,43181818 x 18)

(Bottom product) = 32,727 + 1,045 + 7,773 = 41,545

BM uap = BM liquid = 41,545

Tabel rate uap dan liquida masing-masing bagian

	Rate gas			Rate liquid		
	Kgmol/jam	BM	Kg/jam	Kgmol/jam	BM	Kg/jam
Enriching						
-Atas	8509,04	18,092	153945,5517	7846,797	18,092	141399,277
-Bawah	8509,04	19,258	163867,092	7846,797	20,172	158285,582
Exhausting						
-Atas	8509,04	19,258	163867,092	8563,2817	20,172	172738,518
-Bawah	8509,04	41,545	223470,555	8563,2817	41,545	225723,997

Perhitungan berdasarkan pada beban liquida terbesar yaitu Exhausting bawah

V = 223470,555 kg/jam = 492659,954 lb/jam

L = 225723,997 kg/jam = 497627,859 lb/jam

Bubble point bottom $= T_L = 106°C$

Dew point bottom $= T_V = 109°C$

$$\text{Rata-rata} = \frac{106 + 109}{2} °C = 107,5°C = 225,5°F = 685,5°R$$

$$\rho_V = \frac{41,545}{359} \times \frac{492}{685,5} \times \frac{1}{1} \text{ lb/cuft} = 0,83 \text{ lb/cuft}$$

ρ H_2O liquid pada 107,5°C = 59,488 lb/cuf (Smith, 1959, hlm. 450)

$$\rho_{L\,(Bottom)} = \frac{1}{\frac{0,54545455}{1,049} + \frac{0,02272727}{0,7905} + \frac{0,43181818}{1,0}} \times 59,488 \text{ lb/cuft}$$

$$= \left(\frac{1}{0{,}51998 + 0{,}02875 + 0{,}43181818} \right) \text{ x } 59{,}488 \text{ lb/cuft}$$

$$= 60{,}668 \text{ lb/cuft}$$

$$V = \text{Vapour} = 492659{,}954 \text{ lb/jam} = \frac{492659{,}954}{0{,}083} \text{ cuft/jam}$$

$$= 5935662{,}096 \text{ cuft/jam} = 1648{,}795 \text{ cuft/detik}$$

$$L = \text{Liquid} = 497627{,}859 \text{ lb/jam} = \frac{497627{,}859}{60{,}668} \text{ cuft/jam}$$

$$= 8202{,}477 \text{ cuft/jam}$$

$$= 136{,}708 \text{ cuft/menit} = 1022{,}712 \text{ gpm}$$

Sugden Parachor diperoleh dari tabel 3-317, hlm. 3-240, Perry edisi 5 :

Untuk CH_3COOH $= 2 \text{ x } 4{,}8 + 3 \text{ x } 17{,}1 + 1 \text{ x } 11{,}3 + 60{,}0 = 132{,}2$

Untuk C_2H_5OH $= 2 \text{ x } 4{,}8 + 5 \text{ x } 17{,}1 + 1 \text{ x } 11{,}3 + 1 \text{ x } 43{,}2 = 149{,}6$

Untuk H_2O $= 2 \text{ x } 11{,}3 + 1 \text{ x } 43{,}2 = 65{,}8$

$$\rho_L CH_3COOH = \frac{1{,}049}{60{,}0} \text{ gmol/cm}^3 = 0{,}0175 \text{ gmol/cm}^3$$

$$\rho_L C_2H_5OH = \frac{0{,}7905}{46{,}0} \text{ gmol/cm}^3 = 0{,}0172 \text{ gmol/cm}^3$$

$$\rho_L H_2O = \frac{1{,}0}{18{,}0} \text{ gmol/cm}^3 = 0{,}0556 \text{ gmol/cm}^3$$

Dari Reid, 1977, hlm. 590-591 didapat :

$\sigma\ CH_3COOH = (132,2 \times 0,0175)^4$ dyne/cm = 2,314 dyne/cm

$\sigma\ C_6H_5OH = (149,6 \times 0,0172)^4$ dyne/cm = 2,573 dyne/cm

$\sigma\ H_2O = (65,8 \times 0,0556)^4$ dyne/cm = 3,658 dyne/cm

σ mix $= \sum X_i \sigma_i = (0,54545455 \times 2,314 + 0,02272727 \times 2,573 + 0,43181818 \times 3,658)$ dyne/cm

$= 1,262 + 0,058 + 1,580$

$= 2,90$ dyne/cm $= 2,97$ dyne/cm

Menentukan jumlah plate minim

Dengan persamaan Frenske (Van Winkle, 1967, hlm. 236)

$$Nm = \frac{\text{Log } \{(X_{LK}/X_{HK})_D\ (X_{HK}/X_{LK})_B\}}{\text{Log } \sigma_{av}}$$

Dihitung di neraca massa : $(X_{HK})_D = 0,99671041$

$(X_{LK})_B = 0,02272727$

$$= \frac{\text{Log } (0,00328959/0,99671041)\ (0,43181818/0,02272727)}{\log 2,24024}$$

$$= \frac{\log 789501701,317}{\log 2,24024} = 19,041$$

Menentukan jumlah plate ideal

Dengan metode Gilliard dari Van Winkle, 1967, hlm. 242

$$\frac{R\ op - R\ min}{R\ op + 1} = \frac{11,8488 - 9,873982}{11,8488 + 1} = 0,154$$

Dari fig 5-18, hlm. 243 Van Winkle, 1967 didapat :

$$\frac{N - N_{min}}{N + 1} = 0,50$$

$$\frac{N - 18,307}{N + 1} = 0,50$$

$0,50\,N + 0,50 = N - 18,307$

$N = 37,614 \approx 38$

Menentukan diameter kolom

Vm = 492659,954 lb/jam

Dipakai jarak antar tray = 36 in

Dari Ludwig, 1975 fig 8-18 untuk σ mix = 2,90 dyne/cm dan jarak tray 36 in didapat

harga konstante empiris = K = 520

Rate massa maksimum, lb/jam.ft² = $G = k\sqrt{\rho v\,(\rho_L - \rho v)}$

$= 520\sqrt{0,83\,(60,668 - 0,83)} = 3664,7$ lb/jam.ft²

Diameter kolom, ft = $D = 1,13\sqrt{\dfrac{Vm}{G}}$

$= 1,13\sqrt{\dfrac{492659,954}{3664,7}}$

$= 13,102$ ft $\approx 3,993$ m < 4 m, memenuhi (Ulrich, 1984, **table 4-18**,hlm.188)

Menentukan tinggi kolom

Tinggi kolom = jumlah plate x jarak

= 38 x 36/12 ft = 114 ft

Tinggi total head dan bottom dengan bentuk ellipsoidal

[illegible] diameter = [illegible] ft = 6,680 ft

Total tinggi = ([illegible] + 6,680) ft = 170,68 ft

Dengan menggunakan tebal plate 0,75 in maka

Diameter dalam (Di) = 13,359 ft

Diameter luar (Do) = 13,359 + [2 x (0,75/12)] = 13,484 ft

Penentuan isolasi heat losses

Rata-rata suhu operasi Distillator = 105°C = 221,0°F

Suhu udara luar = 30°C = 86°F

Diameter rata-rata = (13,359 + 13,484) / 2 ft = 13,4215 ft

Exposed area

Head ellipsoidal = 2 (1,09 D²) = 2 [1,09 x (13,4215)²] ft² = [illegible] ft²

Sisi selubung = π (D) (T) = 3,14 x 13,4215 x 164 = [illegible] ft²

Total area = 5197,058 ft²

Digunakan isolator dari Calcium silicate, k = 0,372 Btu in/ft² hr °F dengan tebal dicari

$$U = C \left(\frac{0,372}{0,23} \right)$$ (Frank and Gary, 1978, table 8 - ? hlm 126)

= 1,61739 C Btu/hr ft² °F

C = harga U yang dicari

Panas hilang = q = U . A . ΔT (Frank and Gary, 1978, hlm 1[illegible])

= 1,61739 C x 5197,058 x (221 - 86) Btu/jam

= 1134765,40121 C Btu/jam

= 27234369,629 C Btu/hari = 6863061,1465 C kkal/hari

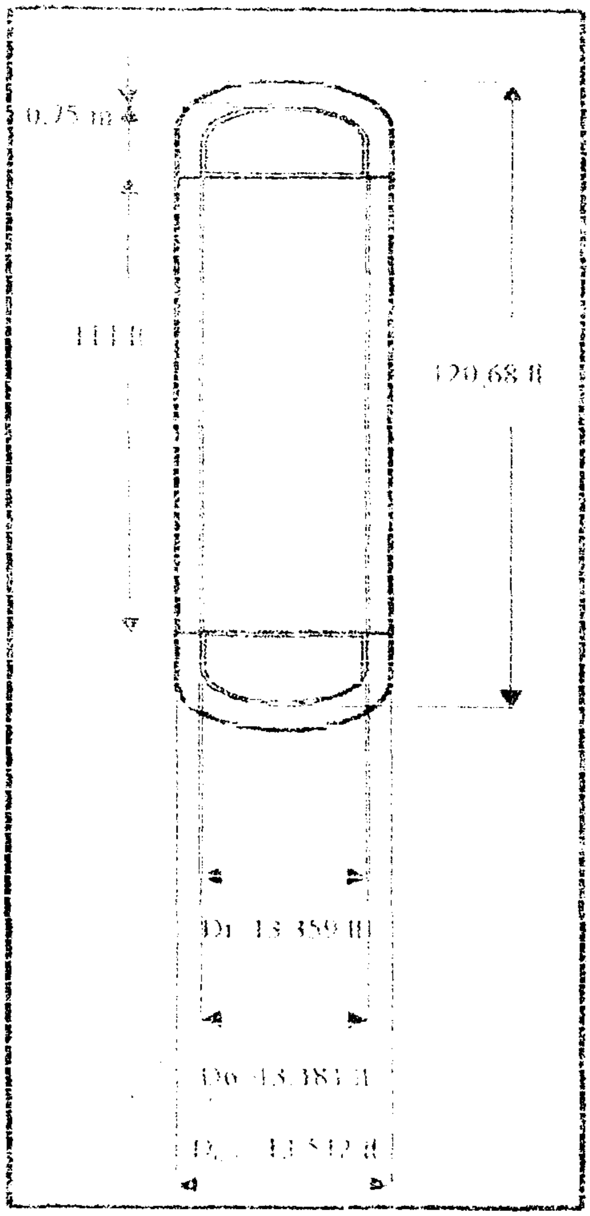
[illegible]1531988,396 kkal – heat losses yang diagihkan di [illegible]

C [illegible] 531988,396 / 6863061,1 [illegible] 1,683 ≈ 1,7 [illegible]

Dengan interpolasi dari tabel 8.7 (Frank and Clary, 1978, hlm.126) dengan kecepatan hembusan angin ke dinding Distilator rata-rata 15 mph,didapat tebal [illegible] 0,347 in

Diameter luar isolasi = Do + ($\frac{2 \times 0,347}{12}$) ft = (13,383 + 0,058) ft = [illegible] ft

11. Spesifikasi Distillator Column (D-130)



Type: Distillator, berbentuk silinder tegak

Kapasitas feed : 341551,801 kg/hari

Tinggi shell : 111 ft

Tinggi total : 120,68 ft

Diameter dalam shell : 13,359 ft

Diameter luar shell : 13,383 ft

Tebal isolasi : 0,347 in

Bahan isolasi : Calcium silicate

Diameter luar isolasi : 13,[illegible]12 ft

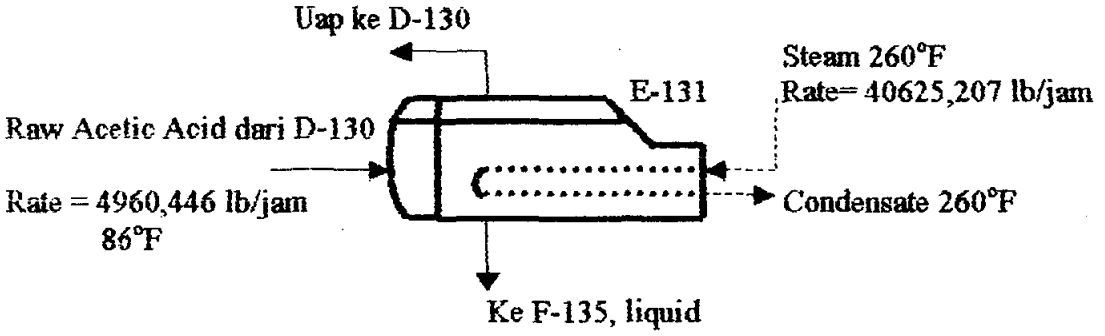
Tebal shell : [illegible]25 in

Bahan shell : Carbon stell, Type SS 316

Jumlah alat : 1 buah

12. REBOILER (E – 131)

Gambar reboiler dan aliran massa



Fungsi : Menguapkan kembali produk bawah dari kolom Distillator.

Type : Shell-tube kettle reboiler

Perhitungan :

Bubble point bottom = 106°C = 379°K = 223°F

Dew pont bottom = 109°C = 382°K = 228°F

Dari perhitungan neraca panas Distillator

Q_R = 230639767,925 kkal/hari = 9609990,3302 kkal/jam

= 38134882,263 Btu/jam

Media pemanas dipakai steam :

T = 260°F

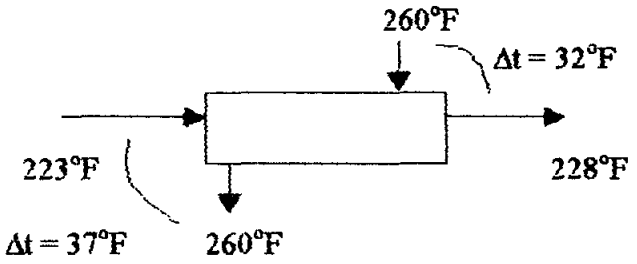
λ = 938,7 Btu/lb

1. Jumlah steam = 975004,979551 lb/hari

= 40625,207 lb/jam

2. L M T D

Ft = 1,0 (salah satu fluida suhunya konstan)



$$LMTD = \frac{37 + 32}{2} = 34\ ^\circ F$$

3. Suhu kalorik

$$Tc = \frac{260 + 260}{2} = 260\ ^\circ F$$

$$tc = \frac{223 + 228}{2} = 225{,}5\ ^\circ F$$

Asumsi : $U_D = 90$ Btu/j $(ft^2)^\circ F$

$$Q = U_D \cdot A \cdot \Delta t$$

$$A = \frac{38134882{,}263}{90\ (34{,}5)} = 12281{,}766\ ft^2$$

Dipilih ukuran pipa :

¾ in OD, 16 BWG, 15/16" triangular pitch, L = 90,4 ft

$$Nt = \frac{A}{\pi \times Do \times L} \longrightarrow a'' = 0{,}1963\ ft^2 \text{ (tab 10)}$$

$$= \frac{12281{,}766}{(0{,}1963)\ 90{,}4} = 692{,}105$$

Dari tabel 9, diperoleh :

ID shell = 29 in

Nt = 692

Passes = 2

U_D koreksi :

A = Nt x a" x L

= 692 x 0,1963 x 90,4 = 12280 ft^2

Q = U_D x A x Δt

$$U_D = \frac{38134882,263}{12280\ (34,5)} = 90,013 \approx 90\ Btu/j\ (ft^2)°F$$

Tube side : fluida panas (steam)	Shell side : fluida dingin
4. Flow area at = 0,302 in^2 (tabel 10, Kern) $at = \frac{Nt \,.\, a\,t}{144\ n}$ $= \frac{692\ (0,302)}{144\ (2)} = 0,726\ ft^2$	
5. Mass velocity $Gt = \frac{W}{At}$ $= \frac{40625,207}{0,726} = 55957,585\ lb/j(ft^2)$	
6. Pada Tc = 260°F μ = 0,018 cp (Kern,hlm. 824,825) = 0,0436 lb/j (ft^2)	

11. Check maximum reflux

$$\frac{Q}{A} = \frac{38134882,263}{12281,766} = 3105 \text{ Btu/j } (ft^2)^\circ F < 20000 \text{ Btu/j } (ft^2)^\circ F$$

$$12.\ Rd = \frac{Uc - U_D}{Uc \times U_D}$$

$$= \frac{600 - 90}{600 \times 90} = 0,009 \text{ j } (ft^2)^\circ F > 0,002 \text{ (memenuhi)}$$

Pressure Drop :

1. Ret = 66353,375

f = 0,0002 (fig 28, Kern hlm. 836)

Dari M.Cabe, 1974, hlm. 915 steam 260°F, spesifik volume = 11,763 ft^3/lb

$$S = \frac{1}{11,763} = 0,085 \text{ lb/ft}^3$$

$$2.\ \Delta Pt = \frac{1}{2} \frac{f\ Gt^2\ L\ n}{5,22\ 10^{10}\ D\ S}$$

$$= \frac{1}{2} \frac{0,0002\ (55957,585)^2\ (90,4)\ (2)}{5,22\ 10^{10}\ (0,00517)\ 0,085} = 0,493 \text{ psi}$$

Gt = 55957,585

$V^2/2g$ = 0,001 (Kern, fig. 27 , hlm. 837)

$$\Delta P_r = \frac{4 \times 2}{0,085} \times 0,01 = 0,094 \text{ psi}$$

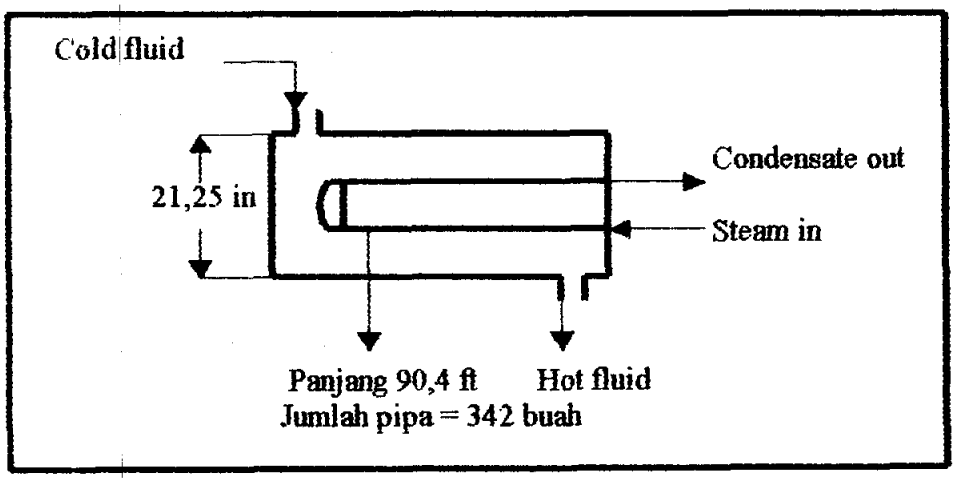
$\Delta P_T = \Delta P_T + \Delta P_r$

$= (0,493 + 0,094)$ psi = 0,587 psi

Ringkasan

R_d dihitung = 0,009	R_d ketentuan minimal = 0,002
ΔP_T dihitung = 0,587 psi	ΔP_T ketentuan maksimum = 10 psi
U_C = 600 Btu/hr ft^2°F	
U_D = 90 Btu/hr ft^2°F	

12. Spesifikasi Reboiler (E-131)



Type = Shell-tube kettle reboiler

Kapasitas panas yang diberikan = 38134882,263 Btu/jam

Luas pemindah panas = 12280 ft^2

Panjang pipa H.E = 90,4 ft

U_D koreksi = 90,013 Btu/j (ft^2°F)

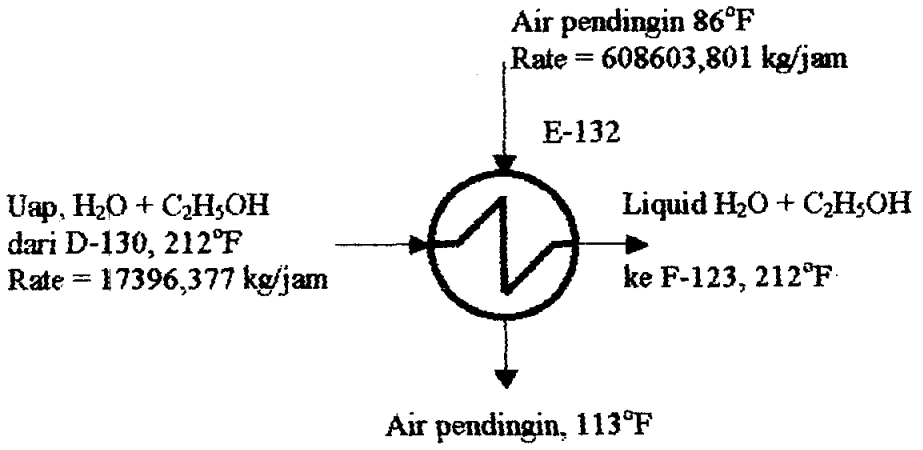
ΔP_T = 0,587 psi

Bahan konstruksi = carbon steel, lapis SS. 316

Jumlah = 1 buah

13. CONDENSER (E – 132)

Gambar condenser dan aliran massa



Fungsi : Untuk mengkondensasikan produk atas Distillator.

Type : Shell and tube heat exchanger

Perhitungan :

1. Dari neraca panas, diperoleh :

Qc = 2190973368,263 kkal/hari = 91290557,011 kkal/jam

= 362264115,122 Btu/jam

W distilat = 417513,060 kg/hari = 38351,802 lb/jam

Jumlah air yang dibutuhkan = 14606491,2175 kg/hari

= 608603,801 kg/jam = 1341719,137 lb/jam

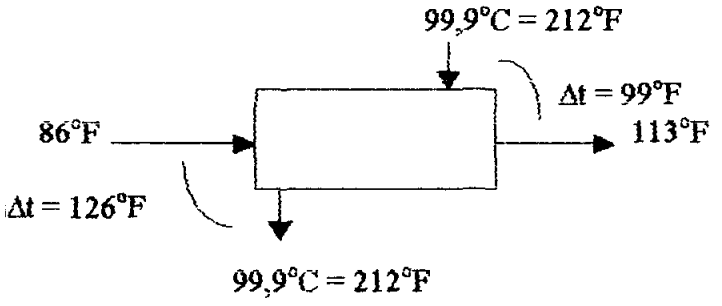
Suhu uap distillate masuk = suhu liquid – keluar

= 99,9°C = 212°F

Suhu air pendingin masuk = 30°C = 86°F

Suhu air pendingin keluar = 45°C = 113°F

2. LMTD



Ft = 1 (salah satunya fluida suhunya konstan)

$$LMTD = \frac{126 + 99}{2} = 112{,}5\ ^\circ F$$

3. Suhu kalorik

$$Tc = \frac{212 + 212}{2} = 212\ ^\circ F$$

$$tc = \frac{113 + 86}{2} = 99{,}5\ ^\circ F$$

Dipilih : 1 ½ in OD, 16 BWG, 1 in square pitch

L = 140 ft

Asumsi : U_D = 200 Btu/j $(ft^2)^\circ F$

$$Q = U_D \cdot A \cdot \Delta t$$

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

$$= \frac{362264115{,}122}{200\ (112{,}5)} = 16100{,}627\ ft^2$$

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

16100,627 = Nt (0,3925) 140

Nt = 293,005

Dari tabel 9, Kern diperoleh :

ID shell = 39 in

Nt = 299

Passes = 2

U_D koreksi :

A = Nt x a" x L

= 299 x 0,3925 x 140 = 16430,05 ft^2

Shell side (fluida panas)	Tube side (air)
4.as = ID x C' B / 144 P_T $= \frac{39 \times 0,1875 \times 12}{1,5 + 0,1875 \times 144} = 0,361\ ft^2$ 5.Gs = $\frac{W}{as}$ $= \frac{38351,802}{0,361}$ = 106237,679 lb/j $(ft^2)°F$ Pada 212°F μ = 0,12 gs (fig. 15 Kern) = 0,2904 lb/jam (ft) De = 0,95 / 12 ft = 0,079 ft	4.at = $\frac{Nt\ a't}{144\ n}$ a't = 1,47 (table 10 Kern) $= \frac{299 \times 1,47}{144\ (2)} = 1,526\ ft^2$ 5.Gt = $\frac{W}{at}$ $= \frac{1341719,137}{1,526}$ = 879239,277 6.Pada t = 113°F μ = 0,7 cp = 1,694 lb/j (ft) Di = 1,37 in = 0,114 ft

Res = D Gs / μ

$$= \frac{0{,}079 \times 106237{,}679}{0{,}2904} = 28900$$

jH = 80 (fig 28 Kern)

k = 0,0137 Btu/hr ft^2 (°F/ft)

(table 5 Kern)

C = 0,47 Btu/lb°F (fig 3 Kern)

$$\frac{C\mu^{1/3}}{k} = \frac{0{,}47 \times 0{,}2904^{1/3}}{0{,}0137}$$

$$= 22{,}718$$

$$ho = jH \frac{k}{De} \frac{C\mu^{1/3}}{k}$$

$$= (80) \frac{0{,}0137}{0{,}079} (22{,}718)$$

= 315,176 Btu/j (ft^2)°F

$$Ret = \frac{D\ Gt}{\mu}$$

$$= \frac{0{,}114\ (879239{,}277)}{1{,}694} = 59169{,}585$$

jH = 200 (Kern, fig 4,hlm. 834)

7.Pada tc = 99,5°F

k = 0,364 Btu/j (ft^2)°F

C = 1,0 Btu/lb (°F)

$$\frac{C\mu^{1/3}}{k} = \frac{1\ \ 1{,}694^{1/3}}{0{,}364}$$

= 1,6696

$$hi = JH \frac{k}{De} \frac{C\mu^{1/3}}{k}$$

$$= 200 \frac{0{,}364}{0{,}114} (1{,}6696)$$

= 1066,201 Btu/j(ft^2)°F

$$9.hio = hi \frac{ID}{OD}$$

$$= 1066{,}201 \frac{1{,}37}{1{,}5}$$ (Kern table 10,hlm.843)

= 973,797 Btu/j(ft^2)°F

$$Uc = \frac{hio \times ho}{hio + ho} = \frac{973{,}797 \times 315{,}76}{973{,}797 + 315{,}76} = 238{,}44 \text{ Btu/j } (ft^2)^\circ F$$

$$Rd = \frac{U_C - U_D}{Uc \times U_D} = \frac{238{,}44 - 200}{238{,}44 \times 200} = 0{,}00081$$

PRESSURE DROP

1'Res = 28900

f = 0,0018 (Kern,fig 29,hlm.839)

2' s = 0,037 (Mc Cabe,1974,hlm.915)

$$N + 1 = \frac{12 \times 140}{12} = 140$$

Ds = 0,079 ft (Kern,fig 28,hlm.838)

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

$$= \frac{0{,}0018 \times (106238)^2 \times 0{,}079 \times 140}{5{,}22 \times 10^{10} \times 0{,}079 \times 0{,}037}$$

= 1,473 psi

1. Ret = 59169,585

f = 0,00017 (Kern,fig 26,hlm.836)

$$2.\ \Delta Pt = \frac{f \times Gt^2 \times L \times n}{5{,}22 \times 10^{10} \times D \times s \times \phi t}$$

$$= \frac{0{,}00017 \times (879239{,}277)^2 \times 140 \times 2}{5{,}22 \times 10^{10} \times 0{,}114 \times 1 \times 1}$$

= 6,184 psi

3. $V^2/2g$ = 0,001 (Kern,fig 27,hlm.837)

ΔPr = 4 n/s (V^2 / 2 g)

$$= \frac{4 \times 2}{1} \times 0{,}001 = 0{,}008$$

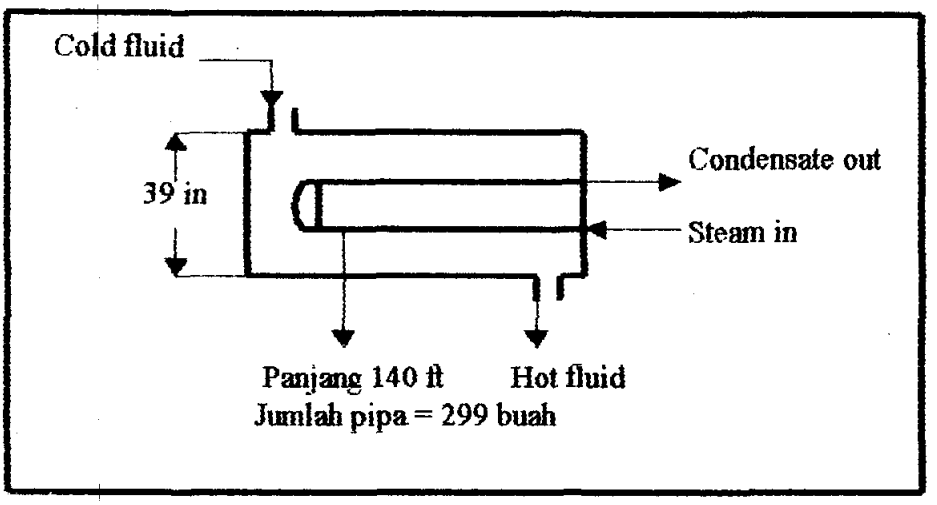
$\Delta P_T = \Delta Pt + \Delta Pr$

= 6,184 + 0,008 = 6,192 psi

Kesimpulan :

Hot gas	h out side	cold liquid
U_C	= 238,44	
U_D	= 200	
ho	= 315,176	
hio	= 973,797	
R_d	= 0,00081	
1,473 psi	ΔP perhitungan	0,0107 psi
10	ΔP diijinkan	10 psi

13. Spesifikasi Condenser (E – 132)

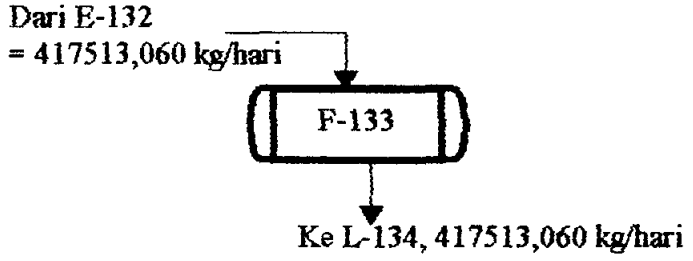


Shell side		Tube side	
ID	: 29"	Jumlah dan panjang	: 299 buah dan 140 ft
Baffle space	: 12"	OD,BWG,pitch	: 1,5", 16, 1" □
Passes	: 1	Passes	: 2

Bahan : Carbon steel

14. ACCUMULATOR (F – 133)

Gambar accumulator dan aliran massa



Fungsi : Menampung sementara Distillate dari Condenser (E-132).

Type : Tangki horizontal dngan tutup samping berbentuk dished.

Dasar pemilihan : Tangki bekerja pada suhu 86,3°C dan tekanan ± 1 atm.

Kebutuhan perhari = 417513,060 kg/hari = 99,9 kg/jam

Density untuk 4,7% C_2H_5OH = 0,99311 kg/lt = 61,970 lb/cuft

(Perry edisi VI,hlm. 3.89)

Digunakan sebuah tangki dengan waktu tinggal 600 detik = 10 menit

(Ulrich, 1984, hlm.249)

$$\text{Volume liquid} = \frac{417513,060}{0,4536 \times 61,970 \times 24 \times 60} \times 10 \text{ cuft} = 103,146 \text{ cuft}$$

Safety allowance 10% (Vilbrandt, 1959, hlm. 152)

Maka volume tangki = 1,1 x 103,146 cuft = 113,461 cuft = 848,802 gallon

Mencari diameter tangki :

(Persamaan-persamaan dan data perhitungan diambil dari Brownell-Young)

Panjang tangki = P = 1 – 2D tangki

$P = \pm 1,5\ D \longrightarrow v = \pi/4 \cdot D^2 \cdot H$

$= \pi/4 \cdot D^2 \cdot 1,5\ D = \pi/4 \cdot 1,5 \cdot D^3$

$$113{,}461 = 0{,}785 \cdot 1{,}5\ D^3$$

$$D^3 = 96{,}358 \longrightarrow D = 4{,}585 \text{ ft}$$

$Rc = (D - 0{,}5)$ ft

$= (4{,}585 - 0{,}5)$ ft $= 4{,}085$ ft

$h = Rc - \sqrt{(Rc^2 - D^2/4)}$

$= 4{,}085 - \sqrt{(4{,}085^2 - 4{,}585^2/4)} = 0{,}704$ ft

$V = 1{,}05 \cdot h^2 \cdot (3\ Rc - h)$

$= 1{,}05 \times 0{,}704^2 \cdot (3 \times 4{,}085 - 0{,}704) = 6{,}011$ ft^3

V silinder = [113,461 – 2 (6,011)] cuft

= 101,439 cuft $\longrightarrow \pi/4 \cdot D^2 \cdot P$

$101{,}439 = 0{,}785 \cdot 4{,}585^2 \cdot P$

Panjang = P = 6,147 ft

Panjang total = (6,147 + 2 x 0,704) ft = 7,555 ft

Tinggi total maksimal = diameter tangki = 4,585 ft

Mencari tekanan design :

Tinggi liquid maksimal = 4,585 ft

P proses = $\rho \cdot g/gc \cdot h/144$

= 61,970 x 1 x 4,585/144 = 1,973 psi

Untuk safety = 20 %

P design = 1,2 x 1,973 psi = 2,368 psi

Tebal tutup kiri kanan (dish = td)

$$td = \frac{P.D}{2 \cdot fe - P} + C$$

Digunakan Carbon steel

f = 12750 psi

e = 0,85 (welded butt joint)

C = 2/16 (faktor korosi)

$$ts = \frac{1,973 \times 4,585 \times 12}{2 \times 12750 \times 0,85 - 1,973} + 2/16 \text{ in} = 0,130 \text{ in}$$

Digunakan tebal = 3/16 in = 0,1875 in

Tebal shell (ts)

$$ts = \frac{P \cdot D}{2 \cdot f \cdot e} + C$$

$$ts = \frac{1,973 \times 4,585 \times 12}{2 \times 12750 \times 0,85} + 0,125 \text{ in} = 0,130 \text{ in}$$

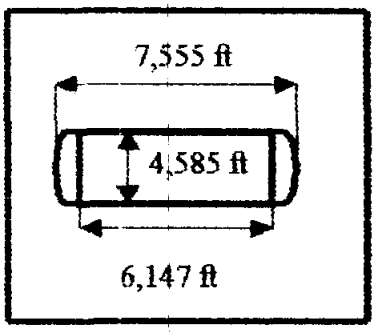
Digunakan tebal 3/16 in = 0,1875 in

14. Spesifikasi Accumulator (F – 133)

Type : Tangki horizontal dengan tutup samping berbentuk dished.

Kapasitas : 848,802 gallon

Dimensi : - diameter shell = 4,585 ft



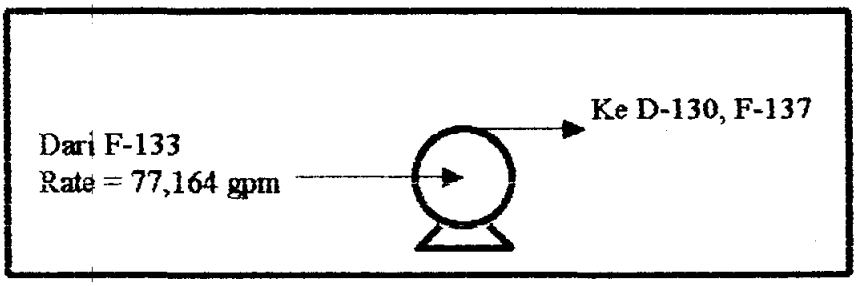
- panjang = 6,147 ft
- tebal shell = 3/16 in
- tebal dished = 3/16 in

Bahan konstruksi : Carbon steel

Jumlah : 1 buah

15. DISTILATE PUMP (L – 134)

Fungsi : Memompa larutan hasil distillate dari Accumulator (F-133) ke Distilator Column (D-130) dan Waste Storage (F-137).



Diameter pipa : 3 in Sch 40

Rate : 77,164 gpm

Head : 16,474 lbf.ft / lbm

Power : 1,50 HP

Jenis : Centrifugal

Bahan : Carbon steel

Jumlah : 1 buah

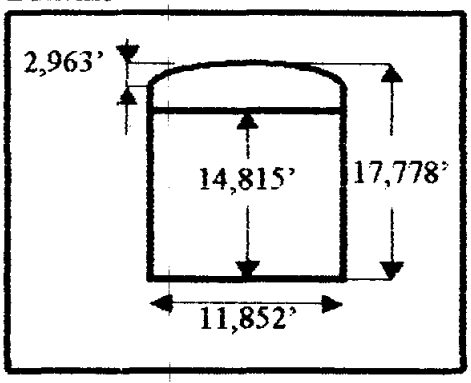
16. ACETIC ACID PRODUCT STORAGE (F – 135)

Fungsi : Untuk menampung produk Acetic Acid dari Distilator Column (D-130).

Type : Silinder tegak, tutup atas berbentuk ellipsoidal, bagian bawah datar.

Kapasitas : 13850,989 gallon

Dimensi : - diameter shell = 8,995 ft



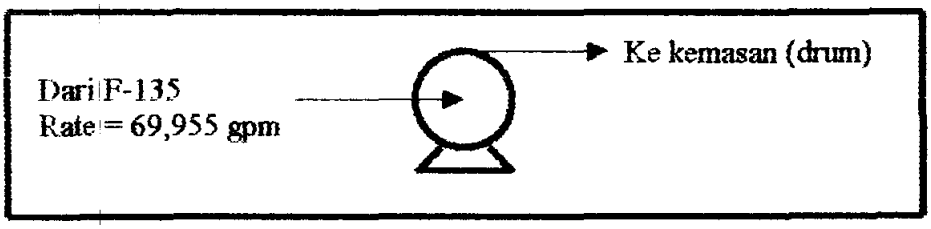
- tinggi shell = 14,815 ft
- tinggi total = 13,494 ft
- tinggi dished = 2,963 ft
- tebal shell = 4/16 in
- tebal dished = 4/16 in

Bahan konstruksi : Carbon steel lapis SS. 316

Jumlah : 1 buah

17. ACETIC ACID PRODUCT PUMP (L – 136)

Fungsi : Memompa produk Acetic Acid 80 % dari Acetic Acid Product Storage (F-135) ke kemasan (drum).



Diameter pipa : 3,0 in Sch 40

Rate : 69,955 gpm

Head : 12,591 lbf.ft / lbm

Power : 0,75 HP

Jenis : Centrifugal

Bahan : Carbon steel, lapis SS. 316

Jumlah : 1 buah

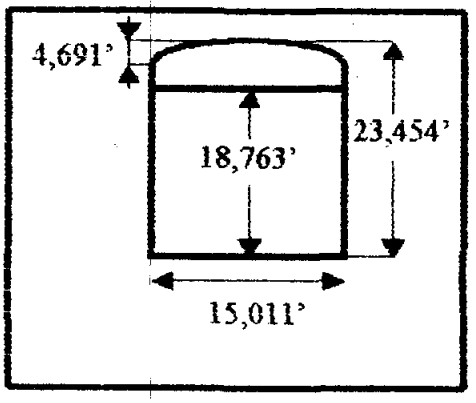
18. WASTE STORAGE (F – 137)

Fungsi : Untuk menampung waste dari Distilator Column (D-130).

Type : Silinder tegak, tutup atas berbentuk ellipsoidal, bagian bawah datar.

Kapasitas : 28139,026 gallon

Dimensi : - diameter shell = 15,011 ft



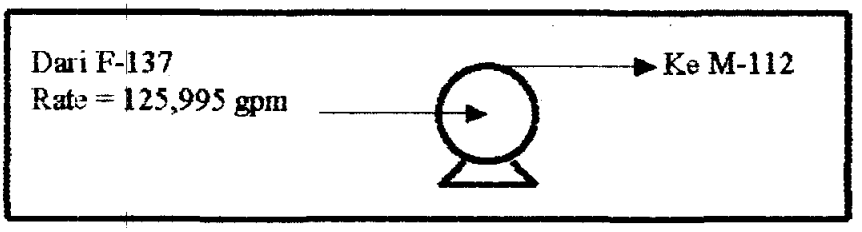
- tinggi shell = 18,763 ft
- tinggi total = 23,454 ft
- tinggi dished = 4,691 ft
- tebal shell = 4/16 in
- tebal dished = 4/16 in

Bahan konstruksi : Carbon steel

Jumlah : 1 buah

19. WASTE PUMP (L – 138)

Fungsi : Memompa waste dari Waste Storage (F-137) ke Material Mixing Tank (M-112).



Diameter pipa : 4 in Sch 40

Rate : 125,995 gpm

Head : 39,638 lbf.ft / lbm

Power : 2,50 HP

Jenis : Centrifugal

Bahan : Carbon steel

Jumlah : 1 buah

APPENDIX D

PERHITUNGAN ANALISA EKONOMI

APPENDIX D

PERHITUNGAN ANALISA EKONOMI

1. Metode Penafsiran Harga Alat

Masalah peralatan proses produksi diputuskan untuk membeli / memesan peralatan pabrik Acetic Acid dari perusahaan / pabrik pembuat alat-alat industri kimia di dalam negeri. Hal ini disebabkan adanya beberapa pertimbangan sebagai berikut :

1. Dengan adanya kemajuan dalam pembuatan peralatan pabrik (industri kimia) di Indonesia yang dapat membuat beberapa peralatan yang cukup sulit. Sebagai contoh : evaporator, filter press, distilator dan lain-lain.
2. Selain itu juga adanya perbedaan yang cukup besar harga peralatan antara buatan dalam negeri dan luar negeri.
3. Serta keadaan ekonomi yang tidak stabil di Indonesia yaitu dengan berubah-ubahnya nilai tukar rupiah terhadap dolar (nilai rupiah sangat jatuh),

2. Metode Penaksiran Harga Bahan Baku dan Produk

Penaksiran harga beli bahan baku dan harga jual produk Acetic Acid dapat diperkirakan / ditanyakan langsung ke pasaran di Surabaya atau di biro statistik.

3. Perhitungan Bahan Baku

3.1. Harga Bahan Baku

- 95% Ethanol

Harga perkilogram = Rp. 5.000

Kebutuhan pertahun = 330 x 32844,766 kg = 10838772,78 kg

Harga beli pertahun = 10838772,78 x Rp 5.000

= Rp. 54.193.863.900

- Medium Bacteria

Harga perkilogram = Rp. 1000

Kebutuhan pertahun = 330 x 110,003 kg = 36300,99 kg

Harga beli pertahun = 36300,99 x Rp. 1000

= Rp. 36.300.990

Total biaya kebutuhan bahan baku selama 1 tahun = Rp. 54.230.164.890

≈ Rp. 54.230.165.000

Harga kebutuhan baku selama 1 bulan produksi = Rp. 4.930.015.000

3.2. Harga Jual Produk Utama dan Samping

Produk utama Acetic Acid

Harga jual perkilogram = Rp. 8.000

Produksi pertahun = 330 x 50000 kg = 16500000 kg

Harga jual pertahun = 16500000 x Rp 8.000

= Rp. 132.000.000.000

Total penjualan produk selama 1 tahun = Rp. 132.000.000.000

Modal penyimpanan produk selama 1 bulan = Rp. 12.000.000.000

Tabel D-1 Harga Peralatan Pabrik Acetic Acid

No	Kode	Nama Alat	Spesifikasi	Bahan	Jml	Total Rp x 1000
01	S-110	95% Ethanol Storage	30007,937 gallon	C.steel	2	400.000
02	L-111	95% Ethanol Pump	18,186 gpm,0,75 Hp	C.steel	1	1.000
03	M-112	Material Mixing Tank	32568,818 gallon	C.steel	1	250.000
04	L-113	Material Mixed Pump	145,116 gpm,5,0 Hp	C.steel	1	1.500
05	R-120	Fermentor	108091,853 gallon	C.steel	10	5.000.000
06	G-121	Air Blower	4493,471 cuft/mnt, 35 Hp	C.steel	10	200.000
07	L-122	Raw Acetic Acid Pump I	1000,853 gpm, 15,0 Hp	C.steel	1	2.000
08	F-123	Raw Acetic Acid Storage	49541,898 gallon	C.steel	2	600.000
09	L-124	Raw Acetic Acid Pump II	62,556 gpm,3,0 Hp	C.steel	1	1.000
10	E-125	Heater	3916204,450 Btu/jam	C.steel	1	100.000
11	D-130	Distilasi Column	341554,801 kg/hari	C.steel	1	800.000
12	E-131	Reboiler	38134882,263 Btu/j	C.steel	1	200.000
13	E-132	Condenser	362264115,122 Btu/j	C.steel	1	120.000
14	F-133	Accumulator	848,802 gallon	C.steel	1	20.000
15	L-134	Distilate Pump	77,164 gpm	C.steel	1	1.000
16	F-135	Acetic Acid Product Storage	13850,989 gallon	C.steel	1	100.000
17	L-136	Acetic Acid Product Pump	69,955 gpm,0,75 Hp	C.steel	1	1.000
18	F-137	Waste Storage	28139,026 gallon	C.steel	1	175.000
19	L-138	Waste Pump	125,995 gpm,2,50 Hp	C.steel	1	1.500
		Perlatan Utilitas :				
20	F-310	Water Bin	130 m^3	Beton	2	40.000
21	L-311	Water Bin Pump	44,03 gal/mnt, 3,0 Hp	C.steel	2	1.000
22	F-312	Tower	15 m^3	C.steel	1	100.000
23	L-313	Fuel Oil Pump	26,404 gal/mnt,3,0 hp	C.steel	2	1.000
24	F-314	Fuel Oil Tank	33960,313 gallon	C.Iron	2	400.000
25	G-315	Cooling Tower	D= 44,946 ft. 100 Hp		1	100.000
26	F-316	Cooled Water Bin	315,112 m^3	C.steel	1	60.000
27	L-317	Cooling Tower Pump	1387,202 gal/mnt, 35 Hp		2	4.000
28	P-318	Chiller	350 kw		1	100.000
29	F-319	Boiler	15702,26 ft^2		1	500.000
30		Bucket and transport, lain lain dan untuk safety (allowance)				720.000
		TOTAL				10.000.000

Tabel D-2 : *Perincian gaji pegawai tiap bulan*

No	Jabatan	Jumlah	Gaji perorang (Rp)	Jumlah (Rp)
1.	Direktur Utama	1	9.200.000	9.200.000
2.	Direktur Teknik & Produksi	1	7.000.000	7.000.000
3.	Direktur Administrasi & Keuangan	1	7.000.000	7.000.000
4.	Sekretaris	1	2.500.000	2.500.000
5.	Kepala bagian	5	3.000.000	15.000.000
6.	Kepala seksi	10	2.000.000	20.000.000
7.	Karyawan operator proses	40	1.210.000	48.000.000
8.	Karyawan kantor/adminitrasi	10	1.000.000	10.000.000
9.	Karyawan utilitas	8	1.000.000	8.000.000
10.	Karyawan M & R	8	1.000.000	8.000.000
11.	Karyawan satpam	12	900.000	10.800.000
12.	Karyawan sopir	2	900.000	1.800.000
13.	Karyawan kebersihan, toilet, taman	2	700.000	1.400.000
14.	Karyawan kontrak (harian lepas)	3	600.000	1.800.000
		104		150.000.000