2. Menara Distilasi (MD-01)

Nama alat = Menara Distilasi

Kode alat = MD-01

Fungsi = Memisahkan metil asetat dan air dari produk asam asetat

Kondisi operasi = 139,35 °C

Tujuan Perancangan

1. Menentukan jenis kolom
2. Menentukan bahan kontruksi kolom
3. Menghitung jumlah *plate*
4. Menentukan lokasi umpan
5. Menentukan dimensi kolom

1. Menentukan kondisi operasi masuk menara distilasi

Dew point

P = 2 atm = 1520 mmhg

T = 139,35 °C = 412,49 °C

Komponen	n	yi	A	B	C	Pio	Pio	Ki = Pio/P	xi = yi/ki
						mmHg	atm		
CH_3OH	1.36	0.01	8.07	1,574.99	238.87	8,094.39	6,151,733.61	5.33	0.00
H_2O	0.18	0.00	8.07	1,730.63	233.43	2,683.88	2,039,752.40	1.77	0.00
CH_3I	4.48	0.03	6.99	1,146.34	236.66	8,695.71	6,608,736.91	5.72	0.01
CH_3OOH	134.33	0.96	7.30	1,479.02	216.82	1,402.92	1,066,219.33	0.92	1.04
	140.35	1.00							1.05

2. Menentukan kondisi operasi atas menara distilasi

Dew point

P = 1 atm = 760 mmhg

T = 69,578°C = 342,73 °K

Komponen	n	yi	A	B	C	Pio	Pio	Ki = Pio/P	xi = yi/ki
						mmHg	atm		
CH_3OH	1.36	0.23	8.07	1,574.99	238.87	925.17	703,126.45	1.22	0.19
H_2O	0.10	0.02	8.07	1,730.63	233.43	228.95	173,998.27	0.30	0.06
CH_3I	4.48	0.75	6.99	1,146.34	236.66	1,756.71	1,335,098.67	2.31	0.32
CH_3OOH	0.06	0.01	7.30	1,479.02	216.82	136.58	103,800.11	0.18	0.05
	6.00	1.00							0.62

Distilasi

Bubble point

P = 3 atm = 2280 mmhg

T = 158,35°C = 431,5°K

Komponen	n	xi	A	B	C	Pio	Pio	Ki = Pio/P	yi = xi*ki
						mmHg	atm		
CH_3OOH	134.27	1.00	7.30	1,479.02	216.82	2,276.85	1,730,403.33	1.00	1.00
H_2O	0.08	0.00	8.07	1,730.63	233.43	4,507.27	3,425,522.57	1.98	0.00
	134.35	1.00							1.00

3. Menentukan *Light Key* (LK) dan *Heavy Key* (HK)

Adapun pemilihan komponen kunci adalah sebagai berikut:

light key : H_2O

heavy key : CH_3COOH

Menentukan distribusi komponen. Metode Shiras

$$\frac{xj \times D}{xjf \times F} = \frac{(\alpha j - 1) \times X_{LKD} \times D}{(\alpha LK - 1) \times X_{LKF} \times F} + \frac{(\alpha LK - \alpha j) \times X_{HKD} \times D}{(\alpha LK - 1) \times X_{HKF} \times F}$$

Komponen i terdistribusi jika:

$$-0{,}01 \le \left(\frac{X_{JD} \times D}{X_{JF} \times F}\right) \le 1{,}01$$

Komponen i tak terdistribusi jika:

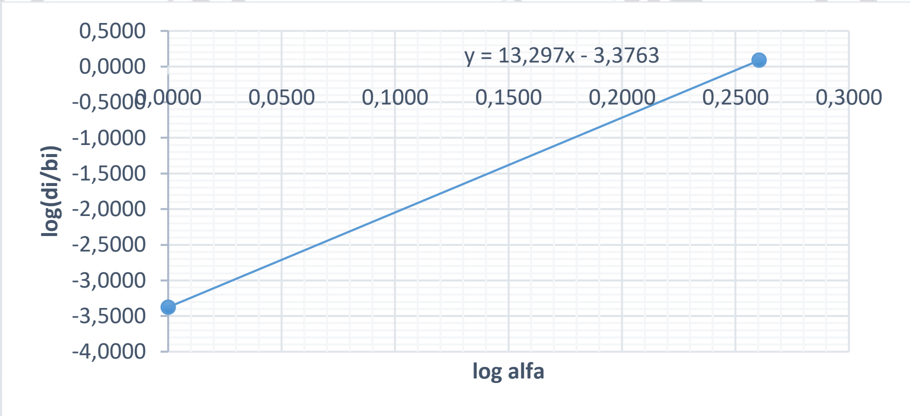
$$\left(\frac{X_{iD} \times D}{X_{iF} \times F}\right) < -0{,}01 \text{ atau } \left(\frac{X_{iD} \times D}{X_{iF} \times F}\right) > 1{,}01$$

Penentuan distribusi komponen

Komponen	alfa-dist	alfa-bott	alfa-ave	**xj,d.D/(zj,f.F)**	Keterangan
CH_3OH	6.773850642	0	0	-0.6685	hasil atas
H_2O	1.676282096	1.979609327	1.82164312	0.5500	terdistribusi
CH_3I	12.86220855	0	0	-0.6685	hasil atas
CH_3COOH	1	1	1	0.0004	terdistribusi

4. **Perhitungan Distribusi *Nonkey Component***

	di	bi	log(di/bi)	alfa	log alfa
1. LK	0.1004	0.0822	0.0872	1.8216	0.2605
2. Hk	0.0565	134.2694	-3.3763	1.0000	0.0000



Log (di/bi) = A+C*log alfa

A = -1,9956

C = 1,9965x

log(di/bi) = -1,9956 + 1,9965x x log Alfa

di = fi/(bi/di+1)

bi = fi/(di/bi+1)

5. **Penentuan jumlah plate minimum**

Jumlah *stage* minimum dihitung degan persamaan fensker (11.58) (Coulson,2003,vol.6,edisi 3,hal.524)

Dengan,

$$Nm=\frac{\log\left(\frac{xLK}{xHK}\right)_D\left(\frac{xHK}{xLK}\right)_B}{\log\alpha\ avgLK}$$

Nmin : jumlah *stage* minimum pada refluks total, termasuk reboiler

αavgLK : relative volatility rata-rata LK

Nm = 13,29 = 14

6. Penentuan refluks minimum (Rmin)

Refluks minimum dihitung dengan menggunakan persamaan underwood

persamaan 11.60, Coulson, 2003, vol.6, edisi 3, hal.525:

$$\sum \frac{\alpha avg\ XD}{\alpha avg - \theta} = Rmin+1$$

persamaan 11.61, Coulson, 2003, vol.6, edisi 3, hal.525:

$$1-q = \sum \frac{\alpha avg\ XF}{\alpha avg - \theta}$$

Nilai q = 1 untuk umpan cair jenuh

Trial θ syarat niali θ harus terletak diantara αHK dan αLK

Trial teta : 5,00851

Komp.	Zif	alfa-feed	alf*Zif	teta
CH_3OH	0.01	5.77	0.06	0.07
H_2O	0.00	1.91	0.00	(0.00)
CH_3I	0.03	6.20	0.20	0.17
CH_3COOH	0.96	1.00	0.96	(0.24)

0,0001 trial teta biar = 0

Diperoleh Teta = 5,00851

Komp.	Xid	alfa dist	alfa*xid	alfi*xdi/(alfi-teta)
CH_3OH	0.2263	6.7739	1.5328	5.8815
H_2O	0.0168	1.6763	0.0281	-0.0141
CH_3I	0.7476	12.8622	9.6152	15.7470
CH_3COOH	0.0094	1.0000	0.0094	-0.0023

21,6

Rm+1 = 21.6121

Rm = 20.6121

Rm/(Rm + 1) = 0.9537

Rop berkisar antara 1.2 - 1.5 Rm

Diambil Rop=1.5 Rm = 30.9181

Maka untuk menghitung jumlah stage ideal dengan korealsi Erbar-Maddox:

Fig. 11.11 Coulson "chem Eng. Vol. 6"

R/(R+1) = 0,9687

diperoleh Nm/N = 0,9

7. Perhitungan jumlah *plate* minimum

Nm = [log{(Xlk/Xhk)d * (Xhk/Xlk)b}]/log alf-lk

(Xlk/Xhk)d = 1,7791

(Xhk/Xlk)b = 1634.0842

Nm = 13,2973

Maka jumlah *stage ideal*

N = 14,7748

= 15

8. Penentuan letak *feed plate*

Menggunakan persamaan Kirkbride (Coulson,2003, vol.6, edisi 3, hal. 526 persamaan 11.62)

$$\log\left(\frac{Nr}{Ns}\right) = 0{,}206 \log\left[\left(\frac{B}{D}\right)\left(\frac{x_{F,HK}}{x_{F,LK}}\right)\left(\frac{x_{B,LK}}{x_{D,HK}}\right)^2\right]$$

Dengan,

Nr : jumlah *stage* diatas *feed stage*, termasuk kondensor

Ns : jumlah *stage* dibawah *feed stage*, termasuk reboiler

B : molar *flow bottom* product

D : molar *flow top product*

XF,HK: fraksi mol HK pada *feed*

XF,LK : fraksi mol LK pada *feed*

XB,LK: fraksi mol LK pada *bottom product*

XD,HK: fraksi mol HK pada *top product*

A	B	C	D	log E
b/d	Xf,hk/Xf,lk	xb,lk/xd,hk	log(a*b*c^2)	0.206*D
22.4100	735.6470	0.0168	0.6657	0.1371

E = Nr/Ns maka E = 1.3713

Nr = 1.371 Ns

Nr + Ns = 15

1,37 x Ns + Ns = 15 ns = 6.325

Ns = 5,262 nr = 8.674

= 7

Nr = 8 (termasuk reboiler)

feed plate = 8,674

9. Perancangan menara distilasi

1. Effisiensi kolom distilasi

Suhu *average top and bottom* = 113,964 °C = 387,1139 °C

α avgLK = 1

Viskositas dihitung dengan persamaan :

$$\log \mu = A + \frac{B}{T} + CT + DT^2$$

Referensi: buku caulson,yaws

Senyawa	A	B	C	D
metanol	- 9,06	1.254,20	0,02	- 0,00002
water	- 10,22	1.792,00	0,02	- 0,00001
metil iodida	- 9,37	1.126,20	0,03	- 0,00003
asam asetat	- 3,89	784,82	0,01	- 0,00001

Komponen	fraksi mol (xi)	μi (cP)	log μi	xi. log μi
CH_3OH	0,01	- 0,68	0,21	0,00202
H_2O	0,00	- 0,61	0,24	0,00032
CH_3I	0,03	- 0,50	0,32	0,01
CH_3OOH	0,96	- 0,42	0,38	0,36
	1,00			0,38

μ liquid campuran = 0.3769 cP

Efisiensi kolom distilasi (*overall*) dihitung dengan korelasi O'Connel yang dinyatakan dengan persamaan 11.67, Coulson, 2003, vol. 6, edisi 3, hal 549:

Eo = 51-32,5 log(μm. αavgLK)

= 64,77 %

Overall efficiency didefinisikan sebagai rasio jumlah *plate* teoritis dengan jumlah *plate actual* yang dinyatakan dengan persamaan :

Eo = N teoritis/ N aktual

= 21, 2672

maka jumlah *real stage* = 22

2. Menentukan sifat-sifat fisika

a. Densitas pada suhu atas

T = 69,578 °C = 342,728 °K

Komponen	BM (kg/kmol)	Distilat (kg/jam)	yd,D	*P* liquid (kg/m3)	yd/*p*L
CH_3OH	32.04	43.47	0.01	744.22	0.000013
H_2O	18.00	1.81	0.001	985.63	0.000001
CH_3I	141.94	636.13	0.03	2,131.46	0.000015
CH_3COOH	60.05	3.39	0.96	995.23	0.000962
Total		684.79	1.00		0.000978

$$p\ liquid = \frac{\sum yD}{\sum \frac{yD}{pi}}$$

ρ *liquid* = 1.022,5 kg/m3

Densitas uap

P = 1 atm = 101300 Pa

R = 8.314,3 m3.Pa/kmol.K

ρ uap = (BM.P)RT

komponen	BM (kg/kmol)	Distilat (kg/jam)	yd,D	*P* uap(kg/m3)	yd/*p*L
CH_3OH	32.04	43.47	0.01	1.14	0.01
H_2O	18.00	1.81	0.00	0.64	0.00
CH_3I	141.94	636.13	0.03	5.05	0.01
CH_3COOH	60.05	3.39	0.96	2.13	0.45
Total		684.79	1.00	8.96	0.46

$$p\ uap = \frac{\sum yD}{\sum \frac{yD}{pi}}$$

ρ uap = 2,1896 kg/m3

b. Densitas pada suhu bawah

T = 158,35 °C = 431,5 °K

komponen	BM (kg/kmol)	Bottom(kg/jam)	xb,B	*P* liquid (kg/m3)	xb/*pv*
CH_3OH	32.04	-	-	634.57	-
H_2O	18.00	1.48	0.00	893.70	0.00
CH_3I	141.94	-	-	1,809.38	-
CH_3COOH	60.05	8,062.88	1.00	886.66	0.00
Total		8,064.36	1.00		0.00

$$p\ liquid = \frac{\sum xB}{\sum \frac{xB}{pv}}$$

ρ *liquid* = 886,66 kg/m^3

Densitas uap

P = 3 atm = 303900 Pa

R = 8.314,3 m3.Pa/kmol.K

ρ uap = (BM.P)RT

Komponen	BM (kg/kmol)	Bottom (kg/jam)	xb,B	P uap(kg/m3)	xb/pv
CH_3OH	32.04	-	-	2.71	-
H_2O	18.00	1.48	0.0006	1.52	0.0004
CH_3I	141.94	-	-	12.02	-
CH_3COOH	60.05	8,062.88	1.00	5.09	0.20
Total		8,064.36	1.00	21.35	0.20

$$p\ uap = \frac{\sum xB}{\sum \frac{xB}{pv}}$$

ρ uap = 5,079 kg/m^3

3. Menghitung tegangan permukaan

Tegangan permukaan dihitung dengan persamaan Sudgen:

$$\sigma = \left[\frac{Pch(\rho L - \rho v)}{M}\right] \times 10^{-12}$$

Keterangan:

σ = Tegangan permukaan (dyne/cm)

Pch = Sudgen's parachor

Pl = Densitas Cairan (kg/m^3)

pv = Densitas uap (kg/m^3)

M = Berat molekul (kg/kmol)

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Table 8.7. Contribution to Sugdens's parachor for organic compounds (Sugden, 1924)

Atom, group or bond	Contribution	Atom, group or bond		Contribution
C	4.8	Si		25.0
H	17.1	Al		38.6
H in (OH)	11.3	Sn		57.9
O	20.0	As		50.1
O_2 in esters, acids	60.0	Double bond:	terminal	
N	12.5		2,3-position	23.2
S	48.2		3,4-position	
P	37.7	Triple bond		46.6
F	25.7	Rings		
Cl	54.3		3-membered	16.7
Br	68.0		4-membered	11.6
I	91.0		5-membered	8.5
Se	62.5		6-membered	6.1

a. *Surface tense* atas

T = 69,57779 °C = 342,7278 °K

Tegangan permukaan (referensi : buku caulson,yaws)

senyawa	A	Tc	N	σ
metanol	32.04	512,58	1,2222	17.71
air	18.00	647,13	0,955	64.56
metil iodida	141.94	528	1,284	22.55
asam asetat	60.05	592,71	1,0703	22.64

Komponen	BM (kg/kmol)	yD,D	Pch	σ	yD.σ
CH_3OH	32,04	0,23	87,40	17,71	4,01
H_2O	18,00	0,02	54,20	64,56	1,08
CH_3I	141,94	0,75	147,10	22,55	16,86
CH_3COOH	60,05	0,01	112,20	22,64	0,21
Total		1,00			22,16

σ mix top = 21,4286 dyne/cm = 0,021428574 N/m

b. *Surface tense* bawah

T = 158,35 °C = 431,5 °K

Tegangan permukaan (referensi : buku caulson,yaws)

Senyawa	A	Tc	N	
metanol	68,329	512,58	1,2222	7,174783
air	132,674	647,13	0,955	46,44952
metil iodida	86,54	528	1,284	9,760859
asam asetat	57,05	592,71	1,0703	14,15971

Komponen	BM (kg/kmol)	yD,D	Pch	σ	yD.σ
CH_3OH	32,04	-	87,40	7,17	-
H_2O	18,00	0,00	54,20	46,45	0,03
CH_3I	141,94	-	147,10	9,76	-
CH_3COOH	60,05	1,00	112,20	14,16	14,15
Total		1,00			14,18

σ *mix bottom* = 14,179 dyne/cm = 0,01417 N/m

4. *Flow rate*

Top product D = 684.7908 kg/jam

Vapour rate V = (1+R)*D = 21.857,251 kg/jam

Liquid rate = L= RD = 21.172,46 kg/jam

Bottom product B = F - D = 8.064,3582 kg/jam

Lm`- Vm` = 8.064,3582 kg/jam

Lm`/Vm` = 4,131

Vm` = 2.575.55 kg/jam

Lm` = 10.639,91 kg/jam

5. ***Physical Properties***

Number of real stage = 22 *stage*

Seksi atas

rho L = 1.022.506 kg/m^3

rho V = 2,189 kg/m^3

ST = 0,022 N/m

Seksi bawah

rho L = 886,662 kg/m^3

rho V = 5,079 kg/m^3

ST = 0,014 N/m

6. ***Enriching section***

R = 30.9181

Lo = R+D

V1 = Lo+D

Temperature = 69,577 °C = 342,727 °K

Tekanan = 1 atm

Konstanta gas = 0,08205 m^3.atm/kmol.K

Lo = 36,91 kmol/jam

V1 = 42,91 kmol/jam

komponen	yi (vap)	xi (liq)	BM	BM vap	BM liq	*pi*(kg/m^3)	xi.BM/*pi*
CH_3OH	0.23	0.19	32.04	7.25	5.96	744.22	0.01
H_2O	0.02	0.06	18.00	0.30	1.00	985.63	0.00
CH_3I	0.75	0.32	141.94	106.11	45.90	2,131.46	0.02
CH_3COOH	0.01	0.05	60.05	0.57	3.15	995.23	0.00
Total	1.00	0.62		114.22	56.01		0.03

BM *average* untuk fase uap = 114,224 kg/kmol

BM *average* untuk fase cair = 56,0076 kg/kmol

$$\rho\, uap = \frac{P.\, BMavg}{R.T}$$

ρ uap = 4,0619kg/m^3

$$\rho\, liquid = \frac{BM\, avg}{\sum(\frac{yi\, BM}{pl})}$$

$\rho\, liquid$ = 1.661,15

it = *plate spacing*, m

(range 0,15-1) (Coulson dan Richardson,1983, vol.6, edisi 3, hal. 556)

Diambil it = 0,45 m

$$uv = (-0{,}171\, it^2 + 0{,}27\, it\, - 0{,}047)(\, \frac{\rho L - \rho v}{\rho v})^{1/2}$$

uv = 0,8053 m/detik

vw = V × Bmvap

= 684,791 kg/jam

0,1902 kg/s

Lw = Lo × Bmliq

= 2.067,428 kg/jam

= 0,5742 kg/detik

sehingga diameter kolom adalah,

$$Dc = \sqrt{\frac{4\, Vw}{\pi\, \rho v\, Uv}}$$

Dc = 0,2721 m

7. ***Stripping section***

umpan masuk cair jenuh q = 1

persamaan 8.8 Ludwig, 1964

L' = qF+L V'/L = 0.242065095 kmol/jam

L' =177.2600734 kmol/jam

V' = L'-B

= 42.90847658 kmol/jam

Temperature=158,3499926 °C = 431,4999926 °K

Tekanan = 3 atm

Konstanta gas = 0,08205 m^3.atm/kmol.K

komponen	yi (vap)	xi (liq)	BM	BM vap	BM liq	*pi*(kg/m3)	xi.BM/*pi*
CH_3OH	-	-	32.04	-	-	634.57	-
H_2O	0.00	0.00	18.00	0.01	0.02	893.70	0.00
CH_3I	-	-	141.94	-	-	1,809.38	-
CH_3OOH	1.00	1.00	60.05	60.01	59.93	886.66	0.07
Total	1.00	1.00		60.02	59.95		0.07

BM *average* untuk fase uap = 60,024 kg/kmol

BM *average* untuk fase cair = 59,956 kg/kmol

$$\rho\ uap = \frac{P.\ BMavg}{R.T}$$

ρ uap = 5,0861 kg/m3

$$\rho\ \ liquid = \frac{BM\ avg}{\sum(\frac{yi\ BM}{pl})}$$

ρ liquid = 886,66 kg/m^3

it = *plate spacing*, m

(range 0,15-1) (Coulson dan Richardson,1983, vol.6, edisi 3, hal. 556)

Diambil it = 0,45 m

$$uv = (-0{,}171\ it^2 + 0{,}27\ it\ - 0{,}047)(\ \frac{\rho L - \rho v}{\rho v})^{1/2}$$

uv = 0,2334 m/detik

vw = V × Bmvap

= 359,855 kg/jam

0,01 kg/detik

Lw = Lo × Bmliq

= 10.627,1014 kg/jam

= 2,951 kg/detik

sehingga diameter kolom adalah,

$$Dc = \sqrt{\frac{4\ Vw}{\pi\ \rho v\ Uv}}$$

Dc = 0,327 m

8. *Column* diameter

Estimasi awal pers

uv\`top = 0,81 m/s

uv\` bawah = 0,23 m/s

Diameter MD

Dc top = 0,27 m

Dc base = 0,33 m

Flv top = 0,14

FLV base = 2,24

Take tray spacing as = 0.45 m nilai = 0,15-1 m

K = (Coulson, 1983, fig.11.27)

top K1 = 0,08

base K1 = 0,02

Correction for surface tensions

top K1 = 0,082

base K1 = 0,02

top uf =1,76 m/s

base uf = 0,21 m/s

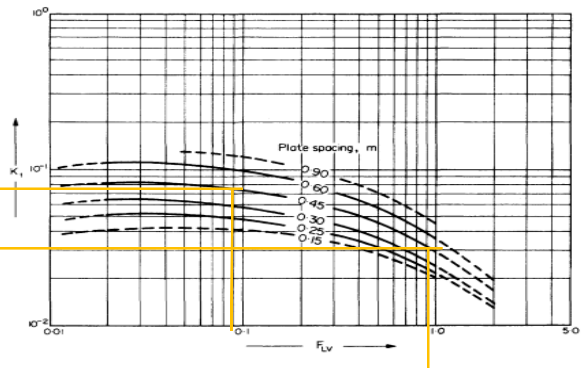


Figure 11.27. Flooding velocity, sieve plates

Design percent flooding at maximaum flow rate 80%-85% =
dpilih 0.8

top uv\` = 1,41

base uv\` = 0,17

Maximum volumetric flow rate

top = 2,77 m^3/s

base = 0,14 m^3/s

Net area required (An)

top = 1,97 m^2

base = 0,84 m^2

As first trial take percent downcomer area of total = 0.12

nilai = 0.05-0.19*Ac Chemical Engineering, vol.6 coulson.p.568

Column cross-sectioned area

top = 2,23 m^2

base = 0,96 m^2

Column diameter

top = 1,69 m 66,42 in

base = 1,10 m 43,47 in

Dipakai diameter yg besar = 1,69 m = 66.42 in

Diambil ukuran yg ada di pasaran = 68 in

= 1.73 m

9. *Liquid flow pattern*

Batas *maximum* aliran cairan untuk *single pass crossflow* sebesar 0,165 (Treybal,1981)

QL = Lw/pL

Maximum vol liquid rate = 0,01 m^3/s (top)

Maka alirannya adalah *single pass (Cross Flow)*

Vol liq rate = 0,003 m^3/s (*base*), *bottom*

Single pass (Cross Flow) = 0,91

10. *Provisional plate design*

Column diameter (Dc) = 1,73 m

Column area (Ac) = 2,34 m^2

Downcomer area (Ad) = 0,28 m^2, pada 12 %

Net area (An) = Ac - Ad = 2,06 m^2

Active area (Aa)=Ac-2 Ad= 1,50 m^2

dipilih untuk trial = 0,06 Aa

Hole area (Ah) = 0,09 m^2

Weir length (fig 11.31)

(Ad/Ac)*100 = 12 didapat lw/Dc= 0,76

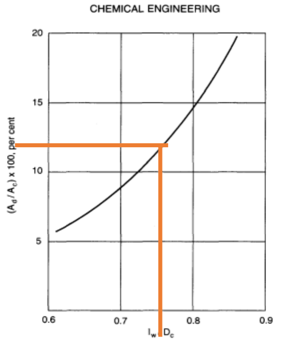


Figure 11.31. Relation between downcomer area and weir length

lw = 0,76 × Dc = 01,31m

untuk material *stainless steel*, (coulson, 1983, hal.573)

ambil tinggi *weir* = hw = 50 mm (nilai=40-90 mm)

diameter *hole* = 3 mm (nilai=2.5-12 mm)

tebal *plate* = 3 mm *Stainless steel*

11. Check weeping

Weeping : liquid yang ada pada plate jatuh bebas ke plate dibawahnya karena tekanan gas dari bawah kurang, disebabkan karena laju alir gas kecil.

Max liquid rate = 2,96 kg/s

dengan percent of turn down = 0,8

Min liquid rate = 2,36 kg/s

Max how = 12,69 mm liquid

Min how = 10,94 mm liquid

pada *minimum rate* (ho + how) = 60,94 mm liquid

Dari Fig 11.30

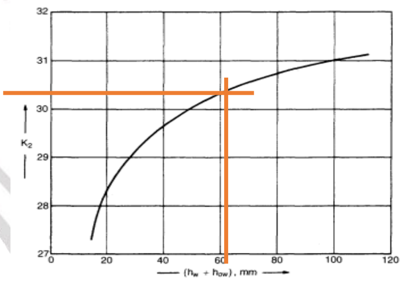


Figure 11.30. Weep-point correlation (Eduljee, 1959)

K2 = 30,30

uh`(min) = 6,85 m/s

Actual min vapour velocity = Min vap. rate / Ah = 24,67 m/s

karena *actual minimum vapor velocity* > Uh min design, maka tidak terjadi *weeping.*

12. *Plate pressure drop*

Dry plate drop (hd), merupakan *pressure drop* yang dihitung pada saat uap mengalir melalui plat kering, dihitung dengan persamaan 11.88, Coulson,1983, hal.575

Max vapour velocity through hole

uh` = 30,83 m/s

dari Fig. 11.34 Coulson,1983 dengan tebal *plate* / diameter *hole* = 1

dan nilai Ah/Ap=Ah/Aa = 0,06

maka Co = 0,86

hd = 140,40 mm *liquid*

residual head

hr = 12,22 mm *liquid*

Total *pressure drop* = ht = hd + (hw + how) +hr

= 215,32 mm *liquid*

pressure drop per plate	= 2.159,78	Pa
Column pressure drop	=47.515,12	Pa
Top presure (1 atm)	= 101.325	Pa
Estimated bottom pres.	= 148.840,12	Pa
	= 1,47 atm	

13. *Downcomer liquid back up*

Downcomer pressure loss

Ambil hap = hw - 10 = 40 mm

Area under apron, Aap = hap*lw = 0,05 m^2

Ad = 0,28 m^2

Karena Aap < Ad maka dipakai Aap pada persamaan perhitungan *head loss* di *downcormer*

hdc = 0,50 mm

Ambil hdc = 1,00 mm

Back up in downcomer

hb = (hw + how) + ht + hdc = 278,51 mm

0,28 < 1/2*(plate spacing+hw)

0,28 < 0,25 m

Tray spacing dapat diterima

Check residense time

tr =Ad*hb*rhoL/Lwd = 27,08 > 3 s satisfactory

Check entrainment

Actual percentage flooding for design area

uv = 1,35 m/s

= 76,33 %

FLV = 0,14

Fig 11.29 didapat w = 0,0018

well below 0,1 , satisfactory

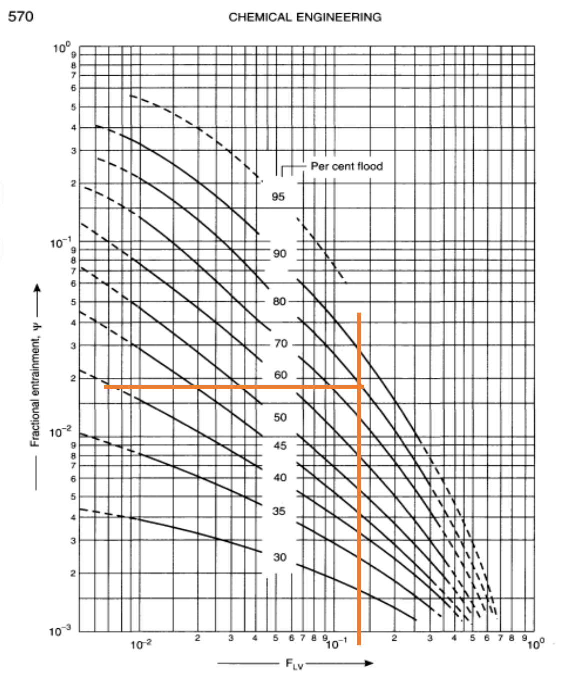
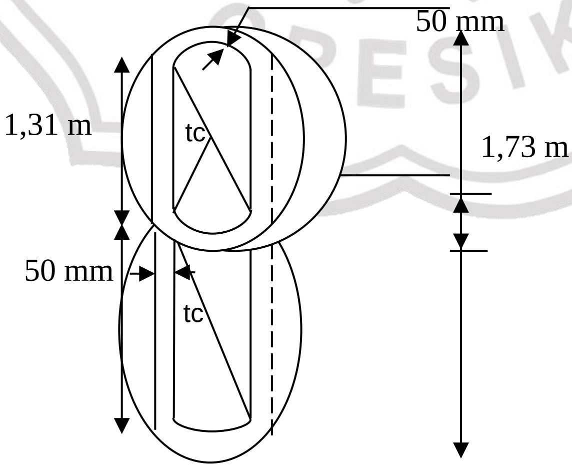


Figure 11.29. Entrainment correlation for sieve plates (Fair, 1961)



14. Perforated area

Fig 11.32 pada lw/Dc = 0,76

teta c =100 derajat

angle subtended at plate edge by unperforated strip = 80 derajat

mean length, unperforated edge strips = 2,34 m

area of unperforated edge strips =0,12 m^2

area of calming zone = 0,12 m^2

Total *area available for perforations*, Ap = 1,26 m^2

Ah / Ap = 0,07 m^2

11.86 atau Fig.11.33 , didapat : lp/dh = 3,4 satisfactory 2.5 - 4

15. Number of hole

Area of one hole = 0,00001 m^2

Number of hole = 12.728,46 holes

12.729

16. Plate spesification

Jumlah Plate	= 22 Plate
Plate ID	= 1,73 m
Hole size	= 3 mm
Hole pitch	= 10,20mm
Active hole	= 12.729 buah
Turn down	= 0,8 *max rate*
Plate material	= *Stainless Steel*
Downcomer material	= *Stainless Steel*
Plate spacing	= 0,45 m
Plate thickness	= 3 mm
Plate pressure drop	= 215,32 mm *liquid* = 0,47 atm

17. Mechanical design

1. Spesifikasi kolom

   Tinggi = (jumlah *stage* actual+1)**tray spacing* + dis + tinggi ruang cairan di bawah

   = 12,35 m

   Diameter (Dc) = 1,73 m = 68 in

R = 0,86 m = 34 in

2. Penentuan kondisi desain

   a. Suhu *design*

      Td = T *top* + 50 °F

      Td = 79,73 °C

   b. Tekanan *design*

      P = P*design* - Pudara luar

      P udara =1 atm, Pop =1 atm

      Pdes = Pop*1.2 = 1,2 atm

      P =0,2 atm = 2,94 psig

      0,0222915 N/mm2 =

      Pd = 1,1*Pop*101325/1e+06

      Pd = 1,45 psig

   c. Material = *Stainless Steel* SA 240 Grade S *Type* 304

      Maximal allowable stress

      S = 15100 psig

      Joint Effisiensi, E = 0,8

      Corrosion All., *c* = 0,125

3. Penentuan tebal *shell* (Ts, mm)

   t = ((P*R)/(S*E-0.6*P))+c

   Maka tebal dinding :

   t = 0,13 in

   Tebal plat standar = 0,1875 in (tebal minimum)

   = 4,76 mm

4. Penentuan jenis dan tebal head (Th, mm)

   Dipilih jenis *Torispherical Dished Head*

   Code = ASME

   Tebal *Head* :

   t = (0.885PRc/(SE-0.1P))+c

   diambil Rc = Dt = 1,73 m = 68 in

   t = 0,14 in

Dipilih tebal plat standar = 0,1875 in (tebal minimum)

= 4,7625 mm

Dari Tabel 5-8 B&Y, sf = 1.5 -3

Diambil panjang sf terkecil, maka sf = 1,5

OD = ID + 2t =68 in

a = ID/2 = 33,81 in

Dari Tabel 5-7 B&Y

untuk t=0.1875 in, OD = 72 in

maka icr = 4 3/8 in

r = 72 in

AB = a-icr = 29,44 in

BC = r-icr = 67,63 n

AC = ((BC^2)-(AB^2))^0.5 = 60,88 in

b = r - AC = 11,12 in

OA = t + b + sf = 12,76 in

5. Tebal isolator

ASUMSI :

1.keadaan steady state

2.suhu udara luar=30 °C

3.suhu dinding luar isolator = 50 °C

jika r1=jari -jari dalam *shell*

r2 = jari -jari luar *shell*

r3 = jari - jari isolator luar +isolator

diameter dalam *shell* = 1,73 m = 5,67 ft

x1= tebal plat dinding *shell* = 4,7625 mm = 0,1875 in

x2= tebal isolator = 0,0156 ft

T= suhu pendingin

T1=s uhu dinding dalam shell =

K	C	F
387,1138927	114,1138927	237,4050069

T2=suhu dinding luar *shell* dicari, trial=

T3=suhu isolator luar = 50 °C

T4=suhu udara luar = 30 °C

BAHAN ASBESTOS dengan sifat-sifat :

rho	=	36	lb/ft3	577,02 kg/m^3
k	=	0,117	btu/j/ft^2/°F	
cp	=	0,25	btu/lb/°F	
E	=	0,96		

Bahan dinding *shell* = *Carbon steel* k = 25 btu/jam/ft/°F

Diameter *shell* = D*shell* = 1,73 m

Tebal plat *shell*= 0,1875 in = 0,015625 ft

q1=konveksi pendingin ke dinding *shell* dalam

q2=konduksi *shell* dalam ke *shell* luar

q3=konduksi *shell* luar ke permukaan luar isolator

q4=konveksi dan radiasi permukaan luar isolator ke udara

a. Menentukan h asbes-udara

T3=	50 °C	122°F	582 °R
T4=	30 °C	86 °F	546 °R
Tf=	40 °C	104 °F	564 °R

daftar A-6 holman pada suhu 104 F sifat-sifat udara ;

kin visco = 0,000017061 m^2/s

k = 0,0272 w/m/C

beta = 0,003194888 1/K

Pr = 0,7

Rho = 1,1279 kg/m^3

Tinggi MD = 8,3 m

GrlxPr= 2.836.623.396.684,39 aliran turbulen karena GrlxPr>1x10E+10, dari persamaan

hc= 3,53 w/m^2/°C= 0,62 btu/h/ft^2

b. Menentukan hr asbes-udara(kern)

eta=	1,714E-09	btu/j/ft^2/F^4		2	554,9011111
koef rad(e)=	0,96		1	293,9174178	
hr=	1,182010907	btu/j/ft^2/°R		1	0,030432855

steady maka q1=q2=q3=q4 dengan q adalah panas yang ditransfer tiap lapisan

q2= k'*A1*(T1-T2)/x1=k'*phi*L*(D+2x1)*(T1T2)/x1

= 4266.667*PHI*L*(293.958-T2)

q3= k'*A2*(T2-T3)/x2=k'*phi*L*(D+2x1+2x2)*(T2T3)/x2

=117*PHI*L*(2.667+2x2)*(T2-122)/x2

q4= (hr+hc)*A3*(T3-T4)=(hr+hc)*Phi*L*(D+2x1+x2x2)*(T3-T4)

= 64.92343*phi*L*(2.667+2x2)

jika q2=q4 didapat persamaan T2=293.9174-0.0304*x2 ….(1)

jika q4=q3 didapat persamaan T2=122+554.901*x2……(2)

sehingga diperoleh dari dua persamaan di atas

x2=	0,309799325 ft	0,094426834	m
	(1)	(2)	(1) - (2)
T2 (F) =	293,9079897	293,9079897	0

Tebal isolator *head* = Tebal isolator *shell* =

0,0944 m

6. Check stress

a. Dead *weight pressure* (WV), kN

Cv = 1,15

(untuk menara distilasi)

WV = 240*Cv*Dm*(Hv+0,8*Dm)*Ts / 1000 , dengan :(pers.13.76 Coulson)

Dm = D + Ts = 1,73 m

Hv = *height of vessel* = 12,35 m

WV = 31,27 kN

b. Berat *plate* (BP), kN

BP = 1,2*At*Jumlah *plate*, dengan :

At = luas area total *plate* = 2,34 m^2

BP = 61,82 kN

c. Berat isolasi (WIS), kN

WIS =PHI* rhos*g*D*Hv*Xis/1000, dengan :

rhos = densitas bahan isolasi = 577,018 kg/m^3

Xis = tebal isolasi = 0,094 m

Approximate volume of insulation =PHI*D*Hv*Xis

= 6,32 m^3

g = 9,81 m/s^2

WS = 35.800,88 N

WS = 35,80 kN

d. berat total (TW), kN

TW = WV + BP + 2*WIS

TW = 164,70 kN

e. *Wind Loading*

diambil *dinamic wind pressure* (DWP) = 1.280 N/m^2

Mean diameter = 1,93 m

Loading (per linier metre) Fw = 2.464,75 N/m

Bending moment of bottom tangent line (Mx), Nm

Mx = w*Hv/^{2}

Mx = 15.219,80 Nm

Analysis of stresses

a. *Pressure stress*

longitudional stress (σl), N/mm^2

σl = Pd*D/(4*Th) = 2,02N/mm^2 (pers.13.64)

#*circumferential stress* (σh), N/mm^2

σh = 2*σl = 4,04 N/mm^2 (pers.13.63)

b. *Dead weight stress* (σw), N/mm2

σw = WV/(PHI*(D + Th)*Th) =1,21 (pers.13.65)

c. *Bending stresses*

OD = D + Th =1.731,96 mm

LV = Phi/64*(OD^4-D^4) = 4,41476E+11 mm^4

σb = Mx/LV*(0,5D+Th) = 0,03 N/mm^2

d. Total *stress*

σz = 1,5*σl + σw + σb = 4,3 N/mm^2

Jadi *shell* aman karena σz < f sehingga tebal *shell* bisa diterima

7. **Diameter pipa pemasukan dan pengeluaran**

Untuk menentukan diameter pipa yang berhubungan dari dan ke menara distilasi digunakan persamaan:

Di,opt = 226*G^(0.5)*rhof^(-0.35)

dengan Di,opt = diameter optimum, mm

G = debit fluida, Kg/detik

rhof = densitas fluida, Kg/m^3

a. Pipa umpan

suhu = 412,49 °K

P = 2 atm = 202.650 Pa

R = 8.314 J/K/mol

Komp.	x mol	kgmol/jam	BM	kg/jam	fr.berat
CH_3OH	0,01	1,36	32,04	43,47	0,0050
H_2O	0,001	0,18	18,00	3,29	0,00038
CH_3I	0,03	4,48	141,94	636,13	0,07
CH_3COOH	0,96	134,33	60,05	8.066,27	0,92
jumlah	1,00	140,35		8.749,15	1,00

rhoL =945,68

rho kg/m^3	vol / 1000 kg	Myui	Yi*Myui
662,21	0,01	0,16	0,0008
914,59	0,0004	0,20	0,0001
1887,64	0,04	0,27	0,02
911,90	1,01	3,94E+16	3,63E+16
	1,020477157		3,63E+16

Rhof = 945,68kg/m^3

= 58,99 lb/cuft

Myucamp = 3,63271E+16cp

= 1,30777E+17 kg/m.jam

G = *Flow rate* =8.749,15 Kg/jam

=2,43 Kg/s

Di,opt = 32,02 mm = 1,26 in

Dipakai pipa standar (IPS)

Nominal *pipe size* =1,25 in

OD =1,66

ID =1,38 in

Schedule number = 40

flow area = 1,5 in^2

check Reynolds = G*D/(a*Myucamp)

Re = 2,42E-12 (aliran laminar)

b. Pipa hasil atas menuju *condensor* (*plate* 1)

suhu = 342,72 °K

P = 1 atm = 101.325 Pa

R = 8.314 J/K/mol

Komp.	x mol	M	x*M	Myui	Myui*Yi	kg/jam	yi
CH_3OH	0,06	32,04	2,03	0,32	0,02	43,47	0,06
H_2O	0,00	18,00	0,05	0,40	0,00	1,81	0,00
CH_3I	0,93	141,94	131,85	0,39	0,36	636,13	0,93
CH_3COOH	0,00	60,05	0,30	2,52184E+20	1,24835E+18	3,39	0,00
Jumlah	1,00		134,23		1,24835E+18	684,79	1,00

rhof =M*P/R/T = 4,77 kg/m^3

= 0,30 lb/cuft

G = Flow rate = 684,79Kg/jam

= 0,19Kg/s

Myucamp = 1,25E+18 cp

= 4,49E+18 Kg/m/jam

Di,opt = 57,04 mm= 2,25 inchi

Dipakai pipa standar (IPS)

Nominal *pipe size* = 2,50 in

OD = 2,88 in

ID = 2,32 in

Schedule number = 80

flow area = 4,23 sq in

check Reynolds

Re = 3,29E-15 aliran laminar

c. Pipa *refluks distilat*

Suhu = 342,728 °K

Komp.	x mol	kgmol/jam	M	flow(kg/j)	x berat
CH_3OH	1,00	1,24	32,04	39,61	0,99
H_2O	0,00002	0,00003	18,00	0,00 05	0,000 01
CH_3I	-	-	141,94	-	-
CH_3COOH	0,004	0,01	60,05	0,30	0,01
jumlah	1,00	1,24		39,91	1,00

Rho L = 745,65

rho kg/m^3	vol / 1000 kg	Myui	Myui*Yi
744,22	1,33	0,32	0,32
985,63	0,00001	0,40	0,00001
-	0,31	0,39	0,26
995,23	0,01	2,52E+20	1,92E+18
	1,34		1,92E+18

rhof = 745,65 kg/m^3

= 46,51 lb/cuft

G = *Flow rate* = 39,91 kg/jam

= 0,01 Kg/s

Myucamp = 1,92E+18cp

= 6,90E+18 kg/m.jam

Di,opt = 2,35 mm= 0,09 inchi

Dipakai pipa standar (IPS)

Nominal pipe size = 0,13 in

OD = 0,41 in

ID = 0,27 in

Schedule number = 40

flow area = 0,06 sq in

Check Reynolds

Re = 1,06E-15 aliran laminar

d. Pipa pengeluaran *bottom* (*plate* Np)

Suhu = 431,5 °K

Komp.	x mol	kgmol/jam	M	flow(kg/j)	x berat
CH_3OH	-	-	32,04	-	-
H_2O	0,00001	0,0008	18,00	0,01	2,02E-06
CH_3I	-	-	141,94	-	-
CH_3COOH	1,00	122,01	60,05	7.326,89	1,00
jumlah	1,00	122,01		7.326,90	1,00

Rhol L = 886,66

rho kg/m^3	vol / 1000 kg	Myui	Myui*Yi
634,57	-	0,13	-
893,70	0,000002	0,17	0,0000004
1809,38	-	0,24	-
886,66	1,13	5,79E+15	5,79E+15
	1,13		5,79E+15

rhof = 886,66kg/m^3

= 55,31 lb/cuft

G = *Flow rate* = 7.326,90 Kg/jam

= 2,04 Kg/s

Myucamp = 5,78958E+15cp

= 2,08425E+16 Kg/m.jam

Di,opt =29,97 mm = 1,18 inchi

Dipakai pipa standar (IPS)

Nominal pipe size = 1,25 in

OD = 1,66

ID = 1,38 in

Schedule number = 40

flow area = 1,50 sq in

Check Reynolds

Re = 1,27E-11 aliran laminar

e. Pipa *refluks bottom*

suhu = 431,4999926 °K

P = 3 atm = 303.975 Pa

R = 8.314 J/K/mol

Komp.	x mol	M	x*M	Myui	Myui*Yi	Kg/jam	Yi
CH_3OH	-	32,04	-	0,13	-	-	-
H_2O	0,02	18,00	0,32	0,17	0,00	1,46	0,02
CH_3I	-	141,94	-	0,24	-	-	-
CH_3COOH	0,98	60,05	58,98	5,79E+15	5,69E+15	80,63	0,98
jumlah	1,00		59,30		5,69E+15	82,09	1,00

rhof = M*P/R/T = 5,02 kg/m^3

= 0,31 lb/cuft

G = *Flow rate* = 82,09 Kg/jam

= 0,02 Kg/s

My camp = 5,69E+15 Cp

= 2,05E+16 Kg/m/jam

Di,opt = 19,40 mm = 0,706 inchi

Dipakai pipa standar (IPS)

Nominal *pipe size* = 1

OD = 1,32

ID = 1,05 in

Schedule number = 40

flow area = 0,86 sq in

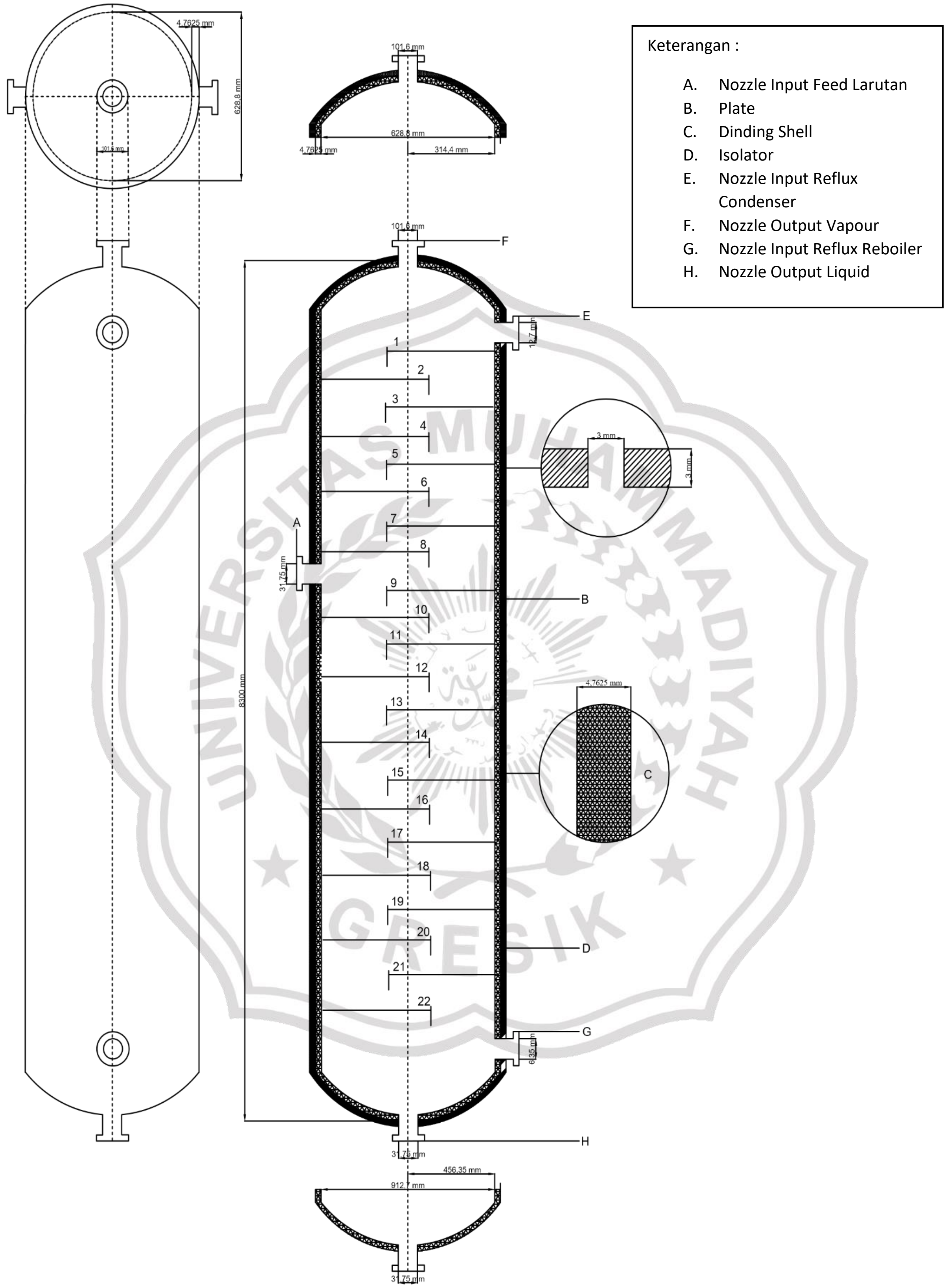
check Reynolds

Re = 1,92E-13aliran laminar

RESUME MENARA DISTILASI (MD-01)

Kode	= MD-01
Fungsi	= Untuk memurnikan asam asetat
Jenis	= *Sieve Tray Tower*
Jumlah	= 1
Kondisi Operasi *Top*	=
- Tekanan	= 1 atm
- Temperature	= 69,58 °C
Kondisi Operasi *Bottom*	=
- Tekanan	= 3 atm
- Temperature	= 158,35 °C
Bahan kontruksi	= *Stainless steel*
Jenis *head*	= *Torispherical dishead head*
Tinggi	= 12,35 m
Tebal *shell*	= 0,005 m
Tebal *head*	= 0,005 m
Tebal isolator	= 0,09 m
Pipa umpan	= 1,25 in
Pipa hasil atas menuju *condensor* NPS	= 2,50 in
Pipa refluks distilat NPS	= 0,13 in
Pipa pengeluaran *bottom* NPS	= 1,25 in
Pipa refluks *bottom* NPS	= 1 in

TAMPAK LUAR ATAS **HEAD (TERBELAH)**



Keterangan :

A. Nozzle Input Feed Larutan
B. Plate
C. Dinding Shell
D. Isolator
E. Nozzle Input Reflux Condenser
F. Nozzle Output Vapour
G. Nozzle Input Reflux Reboiler
H. Nozzle Output Liquid

TAMPAK LUAR SAMPING KANAN **TAMPAK DEPAN (TERBELAH)**