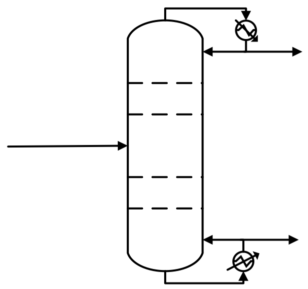
LAMPIRAN

Lampiran 1 Menara Distilasi



Fungsi = memisahkan gliserol sebagai produk samping dari air

Jenis alat = *sieve tray coloumn*

Neraca Massa Alat

Komponen	Feed		Distilat		Bottom	
	kg/jam	kmol/jam	kg/jam	kmol/jam	kg/jam	kmol/jam
$C_{57}H_{104}O_6$	2,142	0,002			2,135	0,002
$C_{18}H_{34}O_2$	30,093	0,107			29,999	0,106
$C_3H_5(OH)_3$	2903,486	31,527	5,789	0,063	2.888,472	31,364
H_2O	13.392,728	743,407	13.354,303	741,082	0,013	0,001
CH_3OH	34,097	0,870	27,877	0,870		
$R\text{-}COOCH_3$	0,029				1,247	
Total	16.362,575	775,913	13.387,969	742,015	2.921,867	31,473

Konstanta Antoine

Diperoleh dari simulasi Hysis

Komponen	Konstanta Antoine					
	A	B	C	D	E	F
CH_3OH	59.840	-6283.000		-6.379		2.000
H_2O	65.930	-7228.000		-7.177		2.000
$C_3H_5(OH)_3$	169.200	-16890.000		-21.810		2.000
$R\text{-}COOCH_3$	180.600	-19150.000		-22.990		2.000
$C_{18}H_{34}O_2$	175.200	-20020.000		-21.910		2.000
$C_{57}H_{104}O_6$	206.000	-32160.000		-24.390		6.000

Menentukan *Relative Volatility*

Volatilitas relatif komponen i terhadap komponen *heavy key* di hitung dengan persamaan :

$$\acute{\alpha}i = \frac{Ki}{K_{HK}}$$

Keterangan	Komponen	Ki	(α)
Light Key	$C_3H_5(OH)_3$	0,008	0,008
Heavy Key	H_2O	0,998	

Komponen		Keterangan	Titik Didih (°C)
Distilat	Bottom		
CH_3OH		*Lighter non key*	64,700
H_2O	H_2O	*Light key*	100,000
$C_3H_5(OH)_3$	$C_3H_5(OH)_3$	*Heavy key*	290,000
	$R\text{-}COOCH_3$	*Heavy non key*	343,850
	$C_{18}H_{34}O_2$	*Heavy non key*	359,850
	$C_{57}H_{104}O_6$	*Heavy non key*	554,230

Menentukan Kondisi Operasi Umpan

Bubble Point

Kondisi umpan menara dirancang pada keadaan *bubble point* keadaan kesetimbangan uap cair dinyatakan dengan persamaan :

$$\sum y_i = \sum k \times x_i = 1$$

dimana :

yi = fraksi mol komponen i dalam fase uap

xi = fraksi mol komponen i dalam fase cair

k = $\frac{Pi}{P}$

Pi = tekanan uap komponen i, (mmHg)

P = tekanan operasi, (atm)

Dengan cara trial and error maka didapatkan kondisi operasi:

Suhu (°C) = 250

Tekanan (atm) = 5,250

Komponen	kg/jam	kmol/jam	Xi	Pi	Pi	Ki	Yi=Ki.Xi
CH_3OH	34,097	0,870	0,001	9523,373	12,531	2,387	0,003
Air	13392,728	743,407	0,958	3981,226	5,238	0,998	0,956
Gliserol	2903,486	31,527	0,041	33,411	0,044	0,008	
R-$COOCH_3$	0,029			7,933	0,010	0,002	
$C_{18}H_{34}O_2$	30,093	0,107		4,042	0,005	0,001	
$C_{57}H_{104}O_6$	2,142	0,002					
Total	16330,310	775,804	1,000				0,959

Dew Point

Kondisi umpan menara dirancang pada keadaan *dew point* keadaan kesetimbangan uap cair dinyatakan dengan persamaan :

$$\sum x_i = \sum \frac{y_i}{K_i} = 1$$

Diambil asumsi bahwa larutan yang ada adalah larutan ideal dan uap yang ada berlaku sebagai gas ideal sehingga fugasitas gas dan aktifitas larutan dianggap = 1, sehingga berlaku :

$$K_i = \frac{P_i}{P}$$

Dengan cara trial and error maka didapatkan kondisi operasi:

Suhu (°C) = 307

Tekanan (atm) = 2

Komponen	kg/jam	kmol/jam	Yi	Pi	Pi	Ki	Xi=Yi/Ki
CH_3OH	34,097	0,870		0,010			0,474
H_2O	13392,728	743,407		25,897	0,034	0,017	0,008
$C_3H_5(OH)_3$	2903,486	31,527		42,088	0,055	0,028	
R-$COOCH_3$	0,029		0,041	169,865	0,224	0,112	0,364
$C_{18}H_{34}O_2$	30,093	0,107	0,958	9450,726	12,435	6,218	0,154
$C_{57}H_{104}O_6$	2,142	0,002	0,001	21335,539	28,073	14,037	
TOTAL	16330,310	775,804					1,000

Menentukan Kondisi Distilat dan *Bottom*

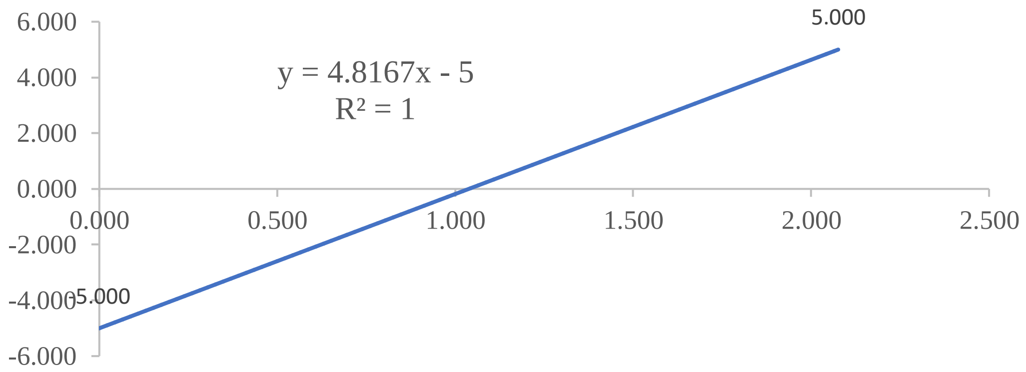
	Distribusi Diinginkan	
HK	Gliserol	1,000
LK	Air	1,000

	Gliserol	kmol/jam	Distribusi
HK	XD	0,000	0,00%
	XB	31,527	100,00%
	log(XD/XB)	-5,000	

	Air	kmol/jam	Distribusi
LK	XD	743,399	100,00%
	XB	0,007	0,00%
	log(XD/XB)	5,000	

Distribusi komponen selain non key

Komponen	α	X=log(α)	Y=log(XD/XB)	X.Y	X^2
CH_3OH	285,038	2,455			
H_2O	119,159	2,076	5,000	10,381	4,310
$C_3H_5(OH)_3$	1,000		-5,000		
R-$COOCH_3$	0,237	-0,624			
$C_{18}H_{34}O_2$	0,121	-0,917			
$C_{57}H_{104}O_6$		-5,054			



Komponen	X=log(α)	Y=log(XD/XB)	XD/XB	XD+XB	**XD**	**XB**
CH_3OH	2,455	6,824	6674498,608	0,870	0,870	
H_2O	2,076	5,000	99999,000	743,407	743,399	0,007
$C_3H_5(OH)_3$		-5,000		31,527		31,527
R-$COOCH_3$	-0,624	-8,008				0,000
$C_{18}H_{34}O_2$	-0,917	-9,418		0,107		0,107
$C_{57}H_{104}O_6$	-5,054	-29,344		0,002		0,002
Total				775,913	744,270	31,643

Komposisi Aliran Distilat (Top, Menuju *Condenser*)

P	5.100	atm	74.949	psi
T	521.517	K	248.367	C

Komponen	kg/jam	kmol/jam	Yi	Pi	Pi	Ki	Xi=Yi.Ki	Xi=Yi/Ki	α	Purity	Tc
CH_3OH	10,329	0,322		9287,491	12,220	2,396	0,001		292,648		239,430
H_2O	13392,715	743,406	0,999	3874,382	5,098	1,000	0,999	1,000	122,082	99,88%	373,980
$C_3H_5(OH)_3$	5,807	0,063		31,736	0,042	0,008		0,010	1,000		450,650
R-$COOCH_3$				7,515	0,010	0,002			0,237		490,850
$C_{18}H_{34}O_2$	0,030			3,805	0,005	0,001			0,120		507,850
$C_{57}H_{104}O_6$											704,730
Total	13408,880	743,792	1,000				1,000	1,010			

Komposisi Aliran Distilat (*Bubble*, Keluar *Condenser*)

P	5,100	atm	74,949	psi
T	522,123	K	248,973	C

Komponen	kg/jam	kmol/jam	Yi	Pi	Pi	Ki	Xi=Yi.Ki	Xi=Yi/Ki	α	Purity	Tc
CH_3OH	10,329	0,322		9376,198	12,337	2,419	0,001		289,738		239,430
H_2O	13392,715	743,406	0,999	3914,544	5,151	1,010	1,009	0,990	120,965	99,88%	373,980
$C_3H_5(OH)_3$	5,807	0,063		32,361	0,043	0,008		0,010	1,000		450,650
R-$COOCH_3$				7,671	0,010	0,002			0,237		490,850
$C_{18}H_{34}O_2$	0,030			3,893	0,005	0,001			0,120		507,850
$C_{57}H_{104}O_6$											704,730
Total	13408,880	743,792	1,000				1,010	1,000			

Komposisi Aliran Bottom (Menuju Reboiler)

P	0,109	atm	1,595	psi
T	553,150	K	280,000	C

Komponen	kg/jam	kmol/jam	Xi	Pi	Pi	Ki	Yi=Ki.Xi	Yi=Xi/Ki	α	Purity	Tc
CH_3OH				14864,109	19,558	180,227			180,119		239,430
H_2O	0,013	0,001		6432,600	8,464	77,995	0,002		77,948		373,980
$C_3H_5(OH)_3$	2897,679	31,464	0,997	82,524	0,109	1,001	0,997	0,996	1,000	98,86%	450,650
R-$COOCH_3$	1,274			20,295	0,027	0,246			0,246		490,850
$C_{18}H_{34}O_2$	30,063	0,106	0,003	11,503	0,015	0,139		0,024	0,139		507,850
$C_{57}H_{104}O_6$	2,142	0,002		0,002				2,939			704,730
Total	2931,171	31,574	1,000				0,999	3,959			

Komposisi Aliran Bottom (Dew, Keluar Reboiler)

P	0,109	atm	1,595	psi
T	582,629	K	309,479	C

Komponen	kg/jam	kmol/jam	Xi	Pi	Pi	Ki	Yi=Ki.Xi	Yi=Xi/Ki	α	Purity	Tc
CH_3OH				22132,078	29,121	268,351			121,166		239,43
H_2O	0,013	0,001		9824,138	12,926	119,117	0,003		53,784		373,98
$C_3H_5(OH)_3$	2897,679	31,464	0,997	182,659	0,240	2,215	2,207	0,450	1,000	98,86%	450,65
R-$COOCH_3$	1,274			45,240	0,060	0,549			0,248		490,85
$C_{18}H_{34}O_2$	30,063	0,106	0,003	28,061	0,037	0,340	0,001	0,010	0,154		507,85
$C_{57}H_{104}O_6$	2,142	0,002		0,012				0,543			704,73
Total	2931,171	31,574	1,000				2,211	1,003			

Mengecek Komponen LK-HK

$$\frac{xj,dD}{zj,fF} = \left(\frac{\alpha_i - 1}{\alpha_{lk} - 1}\right) \cdot \left(\frac{x_{lk,d}.D}{z_{lk,f}.F}\right) + \left(\frac{\alpha_{lk} - \alpha_i}{\alpha_{lk} - 1}\right) \cdot \left(\frac{x_{hk,d}.D}{z_{hk,f}.F}\right)$$

$$\alpha_{avg} = \sqrt{\alpha_D (\alpha_B)}$$

Pers. 9.164 (Shiras) Treyball 3rd edition

Komponen tidak terdistribusi jika		
-0,010	< xj,dD/zj,fF <	1,010

Komponen	Fi (kmol/jam)	Di (kmol/jam)	a top	a bottom	a avg	F1	F2	xj,dD/zj,fF	Validation
CH_3OH	0,870	0,322	292,648	180,119	229,590	2,368	-683,787	-681,419	tidak terdistribusi
H_2O	743,407	743,406	122,082	77,948	97,550	1,000	0,000	1,000	Terdistribusi
$C_3H_5(OH)_3$	31,527	0,063	1,000	1,000	1,000	0,000	500,000	500,000	tidak terdistribusi
R-$COOCH_3$	0,000	0,000	0,237	0,246	0,241	-0,008	503,929	503,921	tidak terdistribusi
$C_{18}H_{34}O_2$	0,107	0,000	0,120	0,139	0,129	-0,009	504,509	504,500	tidak terdistribusi
$C_{57}H_{104}O_6$	0,002	0,000	0,000	0,000	0,000	-0,010	505,179	505,168	tidak terdistribusi

Menentukan Jumlah Plate Minimum

$$N_m + 1 = \frac{\ln[(X_{LK}/X_{HK})_D (X_{HK}/X_{LK})_B]}{\ln(\alpha_{LK/HK})_{AVG}}$$

Nm+1	**4**	Dengan reboiler
Nm	**3**	Tanpa reboiler

Menetukan Refluks Rasio dan Stages Ideal

$$\sum_{1}^{n} \frac{X_{iF}\alpha_i}{\alpha_i - \theta} = 1 - q = \frac{X_{1F}\alpha_1}{\alpha_1 - \theta} + \frac{X_{2F}\alpha_2}{\alpha_2 - \theta} + \cdots$$

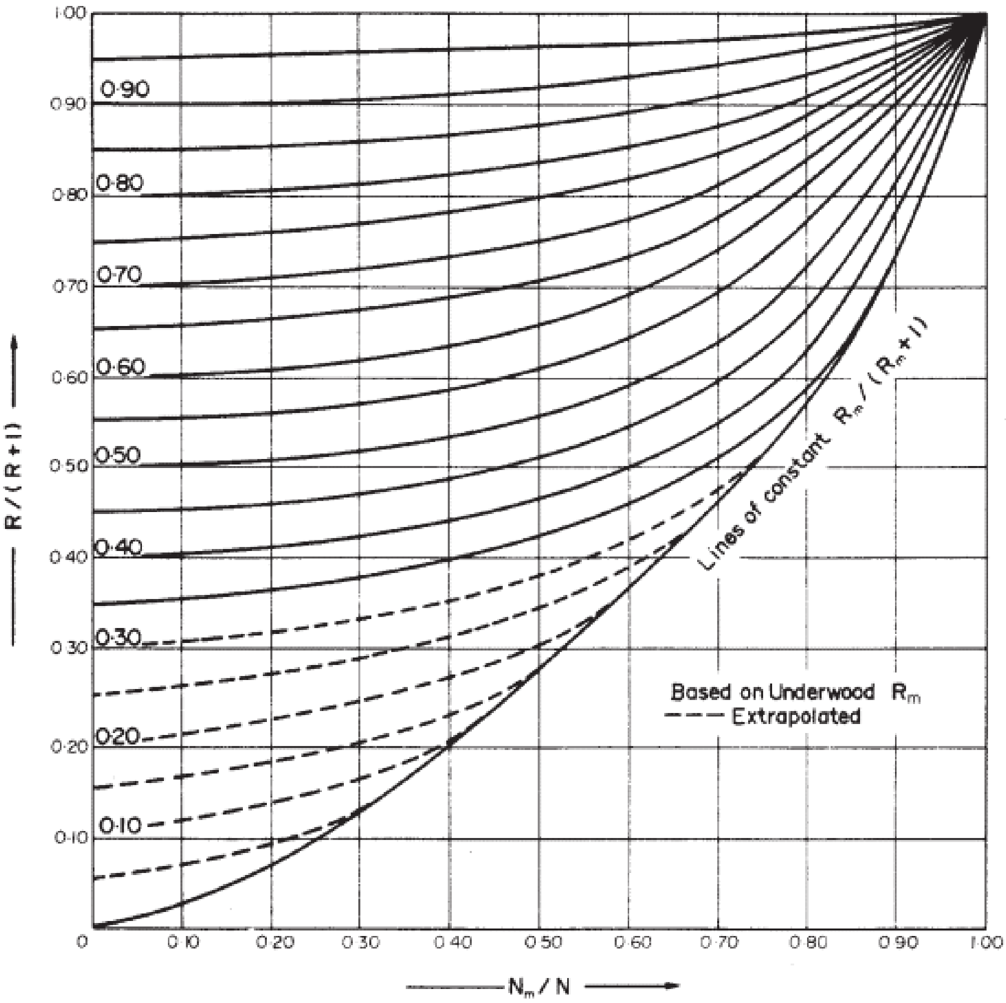
Underwood Method

$$R_m + 1 = \sum_{1}^{n} \frac{\alpha_i X_{iD}}{\alpha_i - \theta}$$

Kondisi Feed Cair Jenuh, q=		1,000			
Trial 0		1,042			
Komponen	Xi,f	Xi,d	a avg	Xi,f.ai/ai-0	ai.Xi,d/ai-0
CH_3OH	0,001	0,000	229,590	0,001	0,000
H_2O	0,958	0,999	97,550	0,969	1,010
$C_3H_5(OH)_3$	0,041	0,000	1,000	-0,964	-0,002
R-$COOCH_3$	0,000	0,000	0,241	0,000	0,000
$C_{18}H_{34}O_2$	0,000	0,000	0,129	0,000	0,000
$C_{57}H_{104}O_6$	0,000	0,000	0,000	0,000	0,000
Total	1,000	1,000		0,006	1,009
Ratio Reflux Minimum (Rm)		0,009			
Actual Reflux (R), 1.2-1.5 Rm		0,010			

Z	A	B	C	D	E	F
0	.00035	.16287	−.23193	5.09032	−8.50815	4.48718
.1	.09881	.32725	−2.57575	10.20104	−12.82050	5.76923
.2	.19970	.14236	−.58646	2.60561	−3.12499	1.76282
.3	.29984	.09393	−.23913	1.49008	−2.43880	1.79486
.4	.40026	.12494	−.49585	2.15836	−3.27068	2.08333
.5	.50049	−.03058	.81585	−2.61655	3.61305	−1.28205
.6	.60063	−.00792	.60063	−2.06912	3.39816	−1.52243
.7	.70023	−.01109	.45388	−1.25263	1.94348	−.83334
.8	.80013	−.01248	.76154	−2.72399	3.85707	−1.68269
.9	.89947	.00420	.38713	−1.14962	1.40297	−.54487
1.0	1.0	-0-	-0-	-0-	-0-	-0-

Interpolasi nilai A-F utk z=			0,009			
z	A	B	C	D	E	F
0,000	0,000	0,163	-0,232	5,090	-8,508	4,487
0,100	0,099	0,327	-2,576	10,201	-12,821	5,769
0,200	0,200	0,142	-0,586	2,606	-3,125	1,763
0,300	0,300	0,094	-0,239	1,490	-2,439	1,795
0,400	0,400	0,125	-0,496	2,158	-3,271	2,083
0,500	0,500	-0,031	0,816	-2,617	3,613	-1,282
0,600	0,601	-0,008	0,601	-2,069	3,398	-1522
0,700	0,700	-0,011	0,454	-1,253	1,943	-0,833
0,800	0,800	-0,012	0,762	-2,724	3,857	-1,683
0,900	0,899	0,004	0,387	-1,150	1,403	-0,545
1,000	1,000	0,000	0,000	0,000	0,000	0,000
0,009	0,009	0,651	0,523	0,567	0,569	0,596



$x = N_m/N$
$y = R/R(R + 1)$
$z = R_m/(R_m + 1)$

For $y = A + Bx + Cx^2 + Dx^3 + Ex^4 + Fx^5$,

x	0.0590	0.0100
y	0.0103	
z	0.0086	
Trial agar = y	0.0101	
Ideal Stages (N)	57	337

$$X = \frac{R - R_{min}}{R + 1},$$

$$Y = \frac{N - N_{min}}{N + 1} = 1 - \exp\left[\left(\frac{1 + 54.4X}{11 + 117.2X}\right)\left(\frac{X - 1}{X^{0.5}}\right)\right],$$

$$N = \frac{N_m + Y}{1 - Y}.$$

X	=	0.0017
Y	=	0.9045
N	=	9
Dipilih Ideal stages =	9	

Menentukan Efisiensi Tray

O'Connell's Equation (WANKAT pers. 10.6)

Temperature Distillat		521,52	K			
Temperature Bottom		553,15	K			
Komponen	μ,D	μ,B	XD	XB	μ,D avg	μ,B avg
CH_3OH	0,009	0,015	0,000	0,000	0,000	0,000
H_2O	0,015	0,023	0,999	0,000	0,015	0,000
$C_3H_5(OH)_3$	5,998	0,012	0,000	0,997	0,001	0,012
$R\text{-}COOCH_3$	0,691	0,007	0,000	0,000	0,000	0,000
$C_{18}H_{34}O_2$	1,997	0,007	0,000	0,003	0,000	0,000
$C_{57}H_{104}O_6$	0,732	0,324	0,000	0,000	0,000	0,000
Total	9,443	0,389	1,000	1,000	0,015	0,012
μ avg	0,014	cp				
aavg LK . μavg	1,326					
Eo	0,495					
Actual Stages	19	Tanpa Reboiler				
Actual Stages	20	Dengan Reboiler				

Menentukan Lokasi Umpan

$$\log\left[\frac{N_r}{N_s}\right] = 0.206 \log\left[\left(\frac{B}{D}\right)\left(\frac{x_{f,HK}}{x_{f,LK}}\right)\left(\frac{x_{b,LK}}{x_{d,HK}}\right)^2\right]$$

Kirkbride Eq. Coulson hal. 526

log Nr/Ns	-1,359	
Nr/Ns	4,37E-02	
Nr+Ns	19	Tanpa Reboiler
Ns	18	dari stage bawah

Plate Design

Perhitungan sifat fisis

a. Densitas pada suhu distilat : 521.5166 K

Fase cair

komponen	V, kmol/jam	x	ρ	ρ.Xi (kg/cum)
CH_3OH	0,322	0,000	270,448	0,117
H_2O	743,406	0,999	375,037	374,843
$C_3H_5(OH)_3$	0,063	0,000	373,753	0,032
R-$COOCH_3$	0,000	0,000	328,079	0,000
$C_{18}H_{34}O_2$	0,000	0,000	326,631	0,000
$C_{57}H_{104}O_6$	0,000	0,000	1373,000	0,000
Total	743,792	1,000		374,992
ρL_mix =	374,992	kg/m³		

Fase gas P = 5.1 Atm

komponen	V, kmol/jam	Yi.BM	ρ (kg/cum)
CH_3OH	0,322	,014	0,002
H_2O	743,406	1,006	2,146
$C_3H_5(OH)_3$	0,063	0,008	0,001
R-$COOCH_3$	0,000	0,000	0,000
$C_{18}H_{34}O_2$	0,000	0,000	0,000
$C_{57}H_{104}O_6$	0,000	0,000	0,000
Total	743,792	18,028	2,148
ρV_mix =	2,148	kg/m³	

R= 0.082057 atm.m3/kmol.K

Z= 1

$$\boldsymbol{\rho = \frac{BM.P}{Z.R.T}}$$

b. Densitas pada suhu bottom : 553.150 K

Fase cair

komponen	L, kmol/jam	x	ρ	ρ.Xi (kg/cum)
CH_3OH	0,000	0,000	125,966	0,000
H_2O	0,001	0,000	731,869	0,017
$C_3H_5(OH)_3$	31,464	0,997	1061,290	1057,602
R-$COOCH_3$	0,000	0,000	668,995	0,003
$C_{18}H_{34}O_2$	0,106	0,003	709,627	2,392
$C_{57}H_{104}O_6$	0,002	0,000	1102,000	0,084
Total	31,574	1,000		1060,098
ρL_mix =	1060,098	kg/m³		

Fase gas P = 0,109 atm

komponen	L, kmol/jam	Yi.BM	ρ (kg/cum)
CH_3OH	0,000	0,000	0,000
H_2O	0,001	0,000	0,000
$C_3H_5(OH)_3$	31,464	91,776	0,219
R-$COOCH_3$	0,000	0,001	0,000
$C_{18}H_{34}O_2$	0,106	0,952	0,002
$C_{57}H_{104}O_6$	0,002	0,068	0,000

R= 0.082 atm.m3/kmol.K

Z= 1.000

$$\boldsymbol{\rho = \frac{BM.P}{Z.R.T}}$$

Total	31,574	92,797	0,222
ρV_mix =	0,222	kg/m³	

Flow Rate

D=	13408.8802	kg/j
V = (R+1)*D=	13548.8752	kg/j
Lo = R*D=	139.9951	kg/j
B =	2931.1712	kg/j
Lm - Vm = B=	2931.1712	kg/j
Lm = F*q+R*D=	16502.5696	kg/j
Vm = Lm-B=	13571.3984	kg/j
Lm/Vm=	1.2160	kg/j

Physical Properties

distilat :			bottom :		
ρV =	2.1485	kg/m3	ρV =	0.2219	kg/m3
ρL =	374.9920	kg/m3	ρL =	1060.0985	kg/m3

Column Diameter

$$F_{LV} = \frac{L_W}{V_W}\sqrt{\frac{\rho_V}{\rho_L}}$$ Liquid-vapor flow factor (Coulson, p. 460)

F_{LV} distilat=	0.0008
F_{LV} bottom=	0.0176

digunakan untuk mencari nilai K1 distilat dan K1 bottom

plate spacing= 0.45 m antara 0.3-0.6 (RK sinnot, P.557)

nilai K1 dari Fig 11.27

K1,distilat=	0.0770
K1,bottom=	0.08

$$u_f = K_1\sqrt{\frac{\rho_L - \rho_V}{\rho_V}}$$ Flooding vapor velocity (Coulson, p. 557)

u_f top=	1.0144	m/s
u_f bottom=	5.5294	m/s

Design percent flooding at maximum flow rate = 80%-85% Coulson page 557

Dipilih velocity= 70%

u_v top =	0.7100	m/s
u_v bottom =	3.8706	m/s

Maximum volumetric flow-rate

distilat=	1.7518	m3/s
bottom=	16.9918	m3/s

Net area required

distilat=	2.4671	m2
bottom=	4.3900	m2

As first trial take percent downcomer area = 12 % Coulson Page 569

Column cross-sectioned area

top=	2.8035	m²
bottom =	4.9886	m²

Column diameter

top=	1.8898	m
bottom=	2.5209	m

Liquid Flow Pattern

Maximum volumetric liquid rate =	0.00432	m³/s

Dari Fig. 11.28 (Coulson, p.569) maka alirannya adalah cross flow (single pass).

Provisional Plate Design

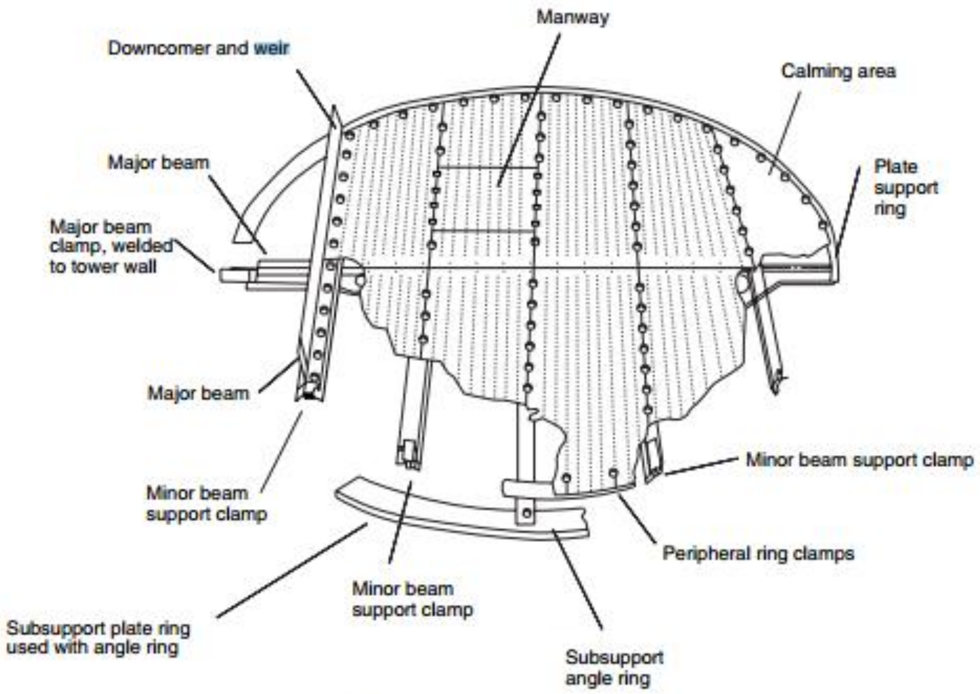


Figure 11.22. Typical sectional plate construction

column diameter Dc =	2.5209	m
column area Ac =	4.9912	m2
downcomer area Ad =	0.5989	m2
net area An = Ac - Ad=	4.3922	m2
active area Aa = Ac - 2Ad=	3.7933	m2
hole area Ah,ambil 6 % dari Aa sebagai first trial=	0.2276	m2
Weir length (Fig. 11.31 Coulson p. 573) untuk (A_d/A_c) x100=	12%	
l_w/D_c =	0.76	
l_w =	1.9159	m
weir height 12% dari plate spacing=	54	mm
hole diameter =	5	mm
plate thickness =	5	mm

Check Weeping

maximum liquid rate (LW) = 4.584 kg/s
Pada percent turn down = 85% , min. liquid rate = 3.896 kg/s
Dengan Francis weir formula dapat dihitung weir liquid crest (Coulson,) :

max h_{ow} =	12.905	mm liquid
min h_{ow} =	11.580	mm liquid
$u_h = \frac{[K_2 - 0,90(25,4 - d_h)]}{\rho v^{1/2}}$		

Pada minimum rate $h_w + h_{ow}$ =	65.580	mm
Fig. 11.30 (Coulson, p.571), K_2 =	30.500	
Minimum design vapor velocity=		
$u_h = \frac{[K_2 - 0{,}90(25{,}4 - d_h)]}{\rho v^{1/2}}$	25.774	m/s
Actual minimum vapor velocity =	minimum vapor rate/Ah	
	63.459	m/s
Memenuhi syarat, karena diatas weep point	**Memenuhi**	

Plate Pressure Drop

Dry plate drop

Maximum vapor velocity through holes

u_h = 74.6573 m/s

Fig. 11.34 (Coulson, p. 576) untuk plate thickness/hole diameter = 1 dan $A_h/A_p \approx A_h/A_a$ = 0,07, maka :

C_o = 0.83

Pressure drop through dry plate

$$h_d = 51\left(\frac{u_h}{C_o}\right)^2 \frac{\rho_v}{\rho_L} =$$ 86.3564 mm liquid

Residual head

$$h_r = \frac{12{,}5x10^3}{\rho_L} =$$ 11.79 mm liquid

Total pressure drop

$$h_t = h_d + (h_w + h_{ow}) + h_r =$$ 165.0525 mm liquid

Pressure drop per plate =	165.0525	mm liquid
Column pressure drop =	1716.4742	Pa
	1.7165	kPa

Downcomer Liquid Back-up

Downcomer pressure loss

Ambil h_{ap} = h_w - 10 =	44.000	mm
Area under apron, A_{ap} = $h_{ap}.l_w$ =	0.084	m²
A_d=	0.599	m²

Karena $A_{ap} < A_d$ maka Aap digunakan dalam persamaan :

0.437 mm

Back-up in downcomer

		232.394	mm
$h_b = (h_w + h_{ow}) + h_t + h_{dc} =$		0.232	m
½ (plate spacing + weir height) =			m
Apakah tray spacing dpt diterima =		Ya	
$t_r = \dfrac{A_d h_{bc} \rho_L}{L_{wd}} =$		138.641	s > 3 s, satisfactory

Check Entrainment

Actual percentage flooding for design area

u_v=	3.869	m/s
percent flooding=	69.96%	
F_{LV} =	0.018	
Fig. 11.29 (Coulson) : ψ =	0.280	

Trial Layout

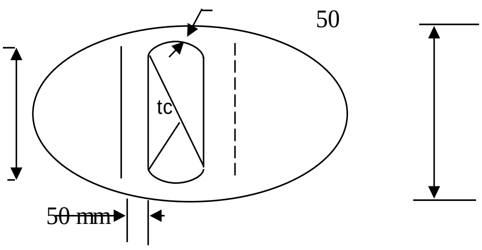
Menggunakan Cartridge-type Construction.

50 mm Unperforated Strip Round Plate Edge : (50-75 mm)

Wide Calming Zone 50 mm

Perforated area 50 mm

1.92 m



2.5209 m

Perforated Area

Dari Fig. 11.32, pada l_w/D_c= 0.76 diperoleh θ_c = 99

Angle subtended at plate by unperforated strip =	81	°
Mean length, unperforated edge strips =	3.4932	m
Area of unperforated edge strips =	0.1747	m²
Area of calming zones =	0.1816	m²
Total area available for perforations A_p =	3.4370	m²
Ah/Ap =	0.0662	

Fig. 11.33 (Coulson) : I_p/d_h =	3.40	

Number of Holes

Area of one hole =	1.96E-05	m²
Number of holes =	11597	

Plate Specification

Plate no.	1.000		Turn down	85%	max rate		
Plate ID	2.521	m	Plate material	stainless steel			
Hole size	5.000	mm	Downcomer material	stainless steel			
Hole pitch	17.000	mm	Plate spacing	0.450	m		
Total no. holes			Plate thickness	5.000	mm		
Active holes	11597.329		Plate pressure drop	165.052	mm liquid	1.716	K.Pa

Menentukan Spesifikasi Menara

Tinggi= (jumlah stage actual - 1 stage reboiler).plate spacing + disengangement + tinggi ruang cairan di bawah

Tinggi =	10.6150	m		
Diameter (IDs)=	2.5209	m	99.2482	in

Menentukan Kondisi Desain

a. Bahan: Carbon Steel SA 283 Grade C

f=	12650	psi

b. Suhu design

T operasi =	537.33	K

c. Tekanan design

P operasi =	5.2	atm
	77.1534	psi
20% over design=	92.5841	psi
Faktor korosi C =	0.125	in
eff. Welding (E)=	0.8	

Menentukan Tebal Shell

Persamaan untuk menghitung minimum thickness : (Brownell, p. 254)

$t_s = \dfrac{P \times \dfrac{D}{2}}{fE - 0{,}6 \times P} + C$	0.5815	in
dipilih tebal standar =	0.7500	in
ODs=IDs + 2 (tebal shell)=	100.7482	in
	2.5590	m

Menentukan Tebal Head

$$tH = \frac{0.885.P.r}{f.E - 0.1.P} + C$$

Jenis : torispherical dished head

Persamaan untuk menghitung minimum thickness : (Brownell, p. 254)

Diambil :		
f =	12650	psi
C =	0.125	in
E =	0.800	
Tebal head =	0.929	in
Dipilih tebal standar=	1.000	in

Menentukan Tinggi Head

$$a = \frac{ID}{2}$$

$$b = r - \sqrt{(BC)^2 - (AB)^2}$$

$$AB = \frac{ID}{2} - (icr)$$

$$BC = r - (icr)$$

$$AC = \sqrt{(BC)^2 - (AB)^2}$$

$$OA = t + b + sf$$

dari tabel 5.7 Brownell hal.90

ODs=	100.748	in
Dipilih OD standar=	66.000	in
icr=	3.625	in
r=	54.000	in
sf=	3.500	in
a=	49.624	in
b=	33.464	in
AB=	45.999	in
BC=	50.375	in
AC=	20.536	in
OA (hH)=	37.964	in
	0.964	m

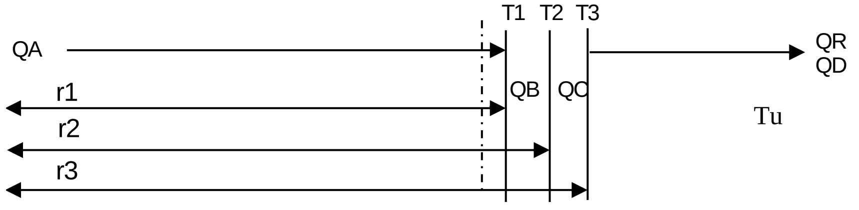
Menentukan Tinggi Total Menara

hR=	Tinggi MD+(2 x tingi head)	
hR=	12.5436	m

Menentukan Tebal Isolator

asumsi

1. Suhu didalam reaktor = suhu permukaan dinding dalam shell = suhu pendingin rata – rata
2. Keadaan steady state
3. Suhu dinding luar isolasi isothermal



Keterangan:

r1 = jari-jari dalam reaktor

r2 = jari-jari luar reaktor

r3 = jari-jari isolator luar

QA = Perp. Konveksi dr Gas ke dinding dlm reaktor

QB = Perp. Konduksi melalui dinding reaktor

QC = Perp. Konduksi melalui isolator

QD = Perp. konveksi dari perm luar isolator

QR = Perp. radiasi

T1 = Suhu dinding dlm MDr = 280°C

T2 = Suhu dinding luar MD = 280°C

T3 = Suhu isolator luar = 120°C

Tu = Suhu udara luar = 30°C

Sifat-sifat udara sebagi berikut

T, K	rho, kg/m3	cp, kj/kg C	miu, kg/m.s x 10^5	v, m^2/s x 10^6	k, w/m.C	alpha, m2/s x 10^4	Pr
300	1.177	1.006	1.846	15.690	0.026	0.222	0.708
350	0.998	1.009	2.075	20.760	0.030	0.298	0.697
400	0.883	1.014	2.286	25.900	0.034	0.376	0.689
450	0.783	1.021	2.484	31.710	0.037	0.422	0.684
500	0.705	1.030	2.671	37.900	0.040	0.556	0.681
550	0.642	1.039	2.848	44.340	0.044	0.653	0.679
600	0.588	1.055	3.018	51.340	0.047	0.751	0.683
650	0.543	1.064	3.177	58.510	0.050	0.858	0.682

sifat-sifat fisis bahan

bahan isolasi → asbestos, dengan sifat-sifat fisis (Appendix, Hollman) :

kis = 0.160 W/m.C

e = 0.960

carbon steel → ks = 39.400 W/m.C

sifat-sifat fisis udara pada suhu Tf (Holman,1988. Daftar A-5)

Tf=	348.150	K
υ=	0.000	m2/s
k=	0.030	W/m.C
Pr=	0.697	
β=	0.003	K-1
μ=	0.000	kg/m.s
g=	9.807	m/s2

keadaan steady state QA=QB=QC=(QD+QR)

r3 = r2 + x		
r1=	1.260	m
r2	1.280	m
L =	10.615	m

kemudian ditrial dengan menggunakan persamaan a,b,c dan d sehingga didapat :

T2 =	553.250	K
x =	0.500	m
sehingga:		
QB=	-17518.251	
QD =	62708.758	
QR =	99764.338	
QC=	3800.087	
QD+QR=Q=	162473.097	
(QD+QR)-QC=	158673.010	
QB-QC=	-21318.338	
Qlost=	31.17%	
jadi tebal isolasi x =	50.000	cm
T2 =	553.250	K

Menentukan Diameter Pipa Pemasukan dan Pengeluaran

Dipilih jenis pipa : Carbon Steel (karena harganya lebih murah dan komponen yang melewati pipa tidak bersifat korosif) (Coulson and Richardson vol.6, 1983, P.221, Eq 5.14)

$$D_{opt} = 293\, G^{0,53} \rho^{-0,37}$$

Nilai densitas pada distilat dan bottom

komponen	A	B	n	Tc	T	(1-T/Tc)^n	- hasil	Bpangkat -	Bpangkat * A	densitas
CH_3OH	0.272	0.249	0.233	512.580	523.120	0.404	0.404	0.570	0.155	155.015
H_2O	0.347	0.274	0.286	647.130	523.120	0.624	-0.624	2.242	0.778	778.294
$C_3H_5(OH)_3$	0.349	0.249	0.154	723.000	523.120	0.820	-0.820	3.127	1.092	1091.718
R-$COOCH_3$	0.280	0.262	0.332	764.000	523.120	0.681	-0.681	2.488	0.696	695.929
$C_{18}H_{34}O_2$	0.282	0.268	0.290	781.000	523.120	0.725	-0.725	2.598	0.734	733.906
$C_{57}H_{104}O_6$					523.120					1262.000

1. **Pipa umpan**

T = 523.1202 K P = 5.2 atm

komponen	F, kmol/jam	x	ρ	ρ.Xi (kg/cum)
CH_3OH	0.870	0.001	155.015	0.174
H_2O	743.407	0.958	778.294	745.688
$C_3H_5(OH)_3$	31.527	0.041	1091.718	44.359

R-COOCH$_3$	0.000	0.000	695.929	0.000
$C_{18}H_{34}O_2$	0.107	0.000	733.906	0.101
$C_{57}H_{104}O_6$	0.002	0.000	1262.000	0.004
Total	775.913	1.000		790.325

ρL_mix =	790.325	kg/m3
G =	4.536	kg/s
$D_{i,opt}$ =	55.300	mm
	2.177	in
Dipakai pipa standar (IPS) :		
Nominal pipe size=	2	in
ID=	***2.245***	in
OD=	2.375	in
Schedule number=	40	

2. Pipa hasil atas menuju condenser

$$\rho = \frac{BM.P}{Z.R.T}$$

T =	521.517	K		
P =	5.100	atm		
komponen	kmol/jam	Yi	Yi.BM	ρ (kg/cum)
CH_3OH	0.322	0.000	0.014	0.002
H_2O	743.406	0.999	18.006	2.146
$C_3H_5(OH)_3$	0.063	0.000	0.008	0.001
R-COOCH$_3$	0.000	0.000	0.000	0.000
$C_{18}H_{34}O_2$	0.000	0.000	0.000	0.000
$C_{57}H_{104}O_6$	0.000	0.000	0.000	0.000
Total	743.792	1.000		2.148

Dan jika digunakan cara di Coulson & Richardson hal 221, maka :

$$D_{opt} = 293G^{0,53}\rho^{-0,37}$$

ρ gas=	2.148	kg/m³
G =	3.725	kg/s
D_{opt} =	443.260	mm
	17.451	in
Dipakai pipa standar (IPS) :		
Nominal pipe size=	**30.000**	in
ID=	***33.250***	in
OD=	34.000	in
Schedule number=	30.000	

3. Pipa refluks distilat

Lo=	139.995	kg/jam		
T =	521.517	°K		
komponen	F, kmol/jam	x	ρ	ρ.Xi (kg/cum)
CH_3OH	0.322	0.000	270.448	0.117

H_2O	743.406	0.999	375.037	374.843
$C_3H_5(OH)_3$	0.063	0.000	373.753	0.032
$R\text{-}COOCH_3$	0.000	0.000	328.079	0.000
$C_{18}H_{34}O_2$	0.000	0.000	326.631	0.000
$C_{57}H_{104}O_6$	0.000	0.000	1373.000	0.000
Total	743.792			374.992
ρL_mix =	374.992	kg/m3		
G =	0.039	kg/s		
$D_{i,opt}$ =	5.849	mm		
	0.230	in		
Dipakai pipa standar (IPS) :				
Nominal pipe size=	**0.125**	in		
ID=	***0.307***	in		
OD=	0.405	in		
Schedule number=	40.000			

4. Pipa pengeluaran bottom

Lm' =	16470.305	kg/jam	
T =	553.150	K	
komponen	kmol/jam	Yi	ρ (kg/cum)
CH_3OH	0.000	0.000	0.000
H_2O	0.001	0.000	0.017
$C_3H_5(OH)_3$	31.464	0.997	1057.602
$R\text{-}COOCH_3$	0.000	0.000	0.003
$C_{18}H_{34}O_2$	0.106	0.003	2.392
$C_{57}H_{104}O_6$	0.002	0.000	0.084
Total	31.574	1.000	1060.098
ρ=	1060.098	kg/m3	

Dan jika digunakan cara di Coulson & Richardson hal 221, maka :

$$D_{opt} = 293\, G^{0,53}\, \rho^{-0,37}$$

ρ cair=	1060.098	kg/m3
G =	4.575	kg/s
D_{opt} =	49.831	mm
	1.962	in
Dipakai pipa standar (IPS) :		
Nominal pipe size=	**2**	in
ID=	***2.067***	in
OD=	2.375	in
Schedule number=	40	

5. Pipa refluks bottom

V=	13571.398	kg/jam		
P=	0.109	atm	T (DP) =	582.6287
komponen	kmol/jam	Yi	Yi.BM	ρ (kg/cum)
CH_3OH	0.000	0.000	0.000	0.000
H_2O	0.001	0.000	0.000	0.000
$C_3H_5(OH)_3$	31.464	0.997	91.776	0.208
$R\text{-}COOCH_3$	0.000	0.000	0.001	0.000
$C_{18}H_{34}O_2$	0.106	0.003	0.952	0.002
$C_{57}H_{104}O_6$	0.002	0.000	0.068	0.000
Total	31.574	1.000		0.211
ρ=	0.211	kg/m3		

Dan jika digunakan cara di Coulson & Richardson hal 221, maka :

$$D_{opt} = 293\, G^{0,53}\, \rho^{-0,37}$$

ρ gas=	0.211	kg/m³
G =	3.770	kg/s
D_{opt} =	1053.443	mm
	41.474	in
Dipakai pipa standar (IPS) :		
Nominal pipe size=	**20**	in
ID=	***19***	in
OD=	20	in
Schedule number=	30	