LAMPIRAN A

Perancangan Menara Distilasi (D-01)

* Mencari Rmin

Dengan komposisi umpan masuk

Komponen	n (kmol/jam)	fraksi mol (xf)	P° (mmHg)	Pt (mmHg)	K	α	$\frac{\alpha.Xf}{\alpha-\theta}$
Benzen	259.2011	0.850353788	836.2891462	760	1.100380456	2.560E+00	1.092E+00
Toluen	45.6145	0.149646212	326.6930491	760	0.429859275	1	-1.092E+00
							5.198E-04

T = 356.5206019

θ = 0.566931195

Dengan komposisi distilat

Komponen	n (kmol/jam)	fraksi mol (Yi)	P° (mmHg)	Pt (mmHg)	K	α	$\frac{\alpha.XD}{\alpha-\theta}$
Benzen	259.0943	0.998303886	2.881647102	760	0.003791641	1.16734907	1.9409301
Toluen	0.4402	0.001696114	2.468539339	760	0.003248078	1	0.0039165
							1.9448466

T = 353.4429973

θ = 0.566931195

Rmin + 1 = 1.944846577

Rmin = 0.944846577 Lo = 1.417269866 D

R/Rmin = 1.5

R = 1.5 Rmin

R = 1.417269866

R = Lo/D

1.417269866 = Lo/D D = 259.5345 kmol/jam

Lo total = 367.830426 kmol/jam

Lo benzene = 367.2065438 kmol/jam

Lo toluene = 0.623882195 kmol/jam

D benzen = 259.0943 kmol/jam

D toluene = 0.4402 kmol/jam

V1 = Lo + D

V1 = 367.830426 + 259.5345

V1 = 627.364926 kmol/jam

* Neraca energi di kondensor :

V1.HV(g) = Lo.ho + D.hD + Qc ho = hD = hL

V1.HV(g) = (Lo +D)HL + Qc V1 = Lo + D

Qc = V1.HV- (Lo + D)HL

$$\Delta H = A\,T + \left(\frac{B}{2}\right)T^2 + \left(\frac{C}{3}\right)T^3 + \left(\frac{D}{4}\right)T^4 + \left(\frac{E}{5}\right)T^5$$

A. HEAT CAPACITY OF GAS Tref = 25°C

298 K

Komponen	A	B	C	D	E	Tmin	Tmax
Benzena	-31.368	-0.4746	-0.00031137	-8.5237E-08	-5.0524E-12	200	1500
Toluena	-24.097	0.52187	-0.00029827	6.122E-08	1.2576E-12	200	1500
Hidrogen	25.399	0.020178	-0.000038549	3.188E-08	-8.7585E-12	250	1500
Metana	34.942	-0.039957	0.00019184	-1.5303E-07	3.9821E-11	50	1500

T = 353.4429973 K

Tref = 298 K

Komponen	n(kmol/jam)	$\int_{Tref}^{T} Cp\,dT$	Hv(g) (kJ/jam)
Benzen	626.3008438	-12313.57999	7712005.541
Toluen	1.064082195	6448.649794	6861.893428
			7718867.434

* V1.HL

B. HEAT CAPACITY OF LIQUID

Komponen	A	B	C	D	Tmin	Tmax
Benzena	-31.662	1.3043	-0.0036078	3.8243E-06	280	506
Toluena	83.703	0.51666	-0.001491	1.9725E-06	197	533
Hidrogen	50.607	-6.1136	0.3093	-0.004148	14	32
Metana	-0.018	1.1982	-0.0098722	0.00003167	92	172

T = 353.4429973 K

Tref = 298 K $\Delta H = A\,T + (B/2)\,T\text{^}2 + (C/3)\,T\text{^}3 + (D/4)\,T\text{^}4 + (E/5)T\text{^}5$

Komponen	n (kmol/jam)	$\int_{Tref}^{T} Cp\,dT$	HL (l) (kJ/jam)
Benzen	626.3008438	7906.129394	4951615.511
Toluen	1.064082195	8986.166182	9562.019436
			4961177.53

Qc = 2757689.904 kJ/jam Kebutuhan air = 1648.483781 kg/jam

T in = 30°C = 303 K n air = 91.58243225 kmol/jam

T out = 50 °C 323 K

Cp air = 1505.578 kJ/kmol K

B. HEAT CAPACITY OF LIQUID

Komponen	A	B	C	D	Tmin	Tmax
Benzena	-31,662	1,3043	-0,0036078	3,8243E-06	280	506
Toluena	83,703	0,51666	-0,001491	1,9725E-06	197	533
Hidrogen	50,607	-6,1136	0,3093	-0,004148	14	32
Metana	-0,018	1,1982	-0,0098722	0,00003167	92	172

HF + QR = HD + HW + QC $\Delta H = A\,T + \left(\frac{B}{2}\right)T^2 + \left(\frac{C}{3}\right)T^3 + \left(\frac{D}{4}\right)T^4 + \left(\frac{E}{5}\right)T^5$

*HF

Komponen	n (kmol/jam)	$\int_{Tref}^{T} Cp\ dT$	HF (l) (kJ/jam)
Benzen	259,2011	8360,948023	2167166,924
Toluen	45,6145	9501,536404	433407,8323
			2600574,757

T = 356,5206019 K

Tref = 298 K

*HD

Komponen	n (kmol/jam)	$\int_{Tref} Cp\ dT$	HF (l) (kJ/jam)
Benzen	259,0943	7906,129394	2048433,061
Toluen	0,4402	8986,166182	3955,710353
			2052388,771

T = 353,4429973 K

Tref = 298 K

*HW

Komponen	n (kmol/jam)	$\int_{Tref}^{T} Cp\ dT$	HF (l) (kJ/jam)
Benzen	0,0107	12471,18039	133,4416302
Toluen	45,2558	14155,11784	640601,1819
			640734,6236

T = 383,7761603 K

Tref = 298 K

*QC = 2757689,904 kJ/jam

QR = HD + HW + QC - HF

QR = 2850238,542 kJ/jam Kebutuhan steam = 1966,08853 kg

Feed :

X light key = 0,850353788

X heavy key = 0,149646212

Distilat :

X light key = 0,998303886

X heavy key = 0,001696114

Bottom :

X light key = 0,000236378

X heavy key = 0,999763622

α top = (Klightkey/Kheavykey)distilat = 2,588855217

α bottom = (Klightkey/Kheavykey)bottom = 2,340357977

α avg = (α top x αbottom)^0,5 = 2,461472722

* Rmin

Rmin = 0,944846577

* Rtotal

Rtotal = 1,417269866

* Nmin (jumlah plate minimum)

Nmin + 1 = ln((Xlightkey/Xheavykey)distilat x (Xheavykey/Xlightkey)bottom) / ln αavg

Nmin + 1 = 16,35015234

Nmin = 15,35015234

Nmin = 16 plate

* Jumlah plate teoritis (N)

Dari grafik ((N-Nmin)/(N+1)) vs ((R-Rmin)/(R+1)) (Perry figure 13-41 halaman 13-35)

(R-Rmin)/(R+1) = 0,195436718

(N-Nmin)/(N+1) = 0,6 Gilliland data points

N = 44 plate DIBAGI 4

* Jumlah plate aktual (N aktual)

α paling ringan pada feed = 2,560E+00

T avg = 364,5799199 K 91,57991986 C 197 F

Data viskositas (Yaws)

Komponen	A	B	C	D
Benzena	-7,4005	1181,5	0,014888	-0,000013713
Toluena	-5,1649	810,68	0,010454	-0,000010486

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

Komponen Feed	n (kmol)	Xi	µ pada Tavg	µi (cP)
Benzena	259,2011	0,850353788	0,278849754	0,237120945
Toluena	45,6145	0,149646212	0,299388525	0,044802359
	304,8156			0,281923303

µ x α = 7,217E-01

Dari grafik 6-47 halaman 306 banchero :

Effisiensi plate = 57% = 0,57

Nactual = (N/Eo) + 1

Nactual = 78,19298246

Nactual = 79 plate

* Letak feed plate

Dengan persamaan Fenske :

Nr/Ns = log((Xlightkey/Xheavykey)distilat x (Xheavykey/Xheavykey)feed) / log ((Xlightkey/Xheavykey)feed x (Xheavykey/Xheavykey) bottom))

Nr/Ns = 3.67088575

Nr/Ns = 3.67088575

Nr + Ns = Nactual

3.67088575 Ns + Ns = 79

4.67088575 Ns = 79

Ns = 16.91328031

Ns = 17

Plate bawah berjumlah = 17

Plate atas berjumlah = 62

Jadi, letak umpan (feed plate) masuk dari plate ke 17 dari bagian bawah.

* Penentuan diameter menara distilasi (D)

Vr = Lo + D

Vr = 627,364926 kmol/jam

Vr = 48949,36138 kg/jam = 107933,3418 lb

1 kg = 2,205 lb

* Penentuan diameter kolom destilasi

Penentuan diameter kolom atas :

Diperkirakan diameter kolom = 6-10 ft

Tray spacing = 24 inch

Diambil tray spacing = 24 inch

Kecepatan alir maksimum :

Data densitas cair (Yaws) A.B^(-(1-T/Tc)^n) gr/mL

Komponen	A	B	n	Tc
Benzen	0,3009	0,2677	0,2618	562,16
Toluen	0,29999	0,27106	0,29889	591,79

ρcairan atas

Komponen	n (kmol/jam)	Xi	ρi (gr/mL)	ρcampuran (gr/mL)
Benzen	259,0943	0,998303886	0,093739905	0,093580911
Toluen	0,4402	0,001696114	0,098068291	0,000166335
	259,5345			0,093747246

ρuap atas

Komponen	n(kmol/jam)	Xi	ρi (gr/L)	ρcampuran (gr/mL)
Benzen	259,0943	0,998303886	67,20043321	0,067086454
Toluen	0,4402	0,001696114	79,26204943	0,000134437
	259,5345			0,067220891

Kecepatan alir maksimum = Vm = Kv $\sqrt{\frac{\rho L - \rho G}{\rho G}}$ = 0,188455107 ft/s

Kv = 0,3 ft/s

(Figure 5.6, Peters, halaman 657)

Kecepatan alir maksimum = 0,188455107 ft/s

Kecepatan alir aktual :

Flooding yang diijinkan = 65-80% (Figure 16-7, Peters, halaman 658)

Diambil kecepatan alir aktual = 0,150764085 ft/s

Diameter kolom atas :

$$D\ atas = \sqrt{\frac{4\ x\ Vr}{\pi\ x\ \rho gas\ atas\ x\ V\ aktual\ x\ 3600}}$$

D atas = 7,769640797 ft 1 ft = 0,305 m

D atas = 2,369740443 m

Diameter kolom bawah :

Diperkirakan diameter kolom = 6-10 ft

Tray spacing = 24 inch

Diambil tray spacing = 24 inch

Data densitas cair (Yaws) A.B^(-(1-T/Tc)^n) gr/mL

Komponen	A	B	n	Tc
Benzen	0,3009	0,2677	0,2618	562,16
Toluen	0,29999	0,27106	0,29889	591,79

ρcairan bawah

Komponen	n (kmol/jam)	Xi	ρi (gr/mL)	ρcampuran (gr/mL)
Benzen	0,0107	0,000236378	0,091381355	2,16005E-05
Toluen	45,2558	0,999763622	0,095366759	0,095344217
	45,2665			0,095365817

ρuap bawah

Komponen	n(kmol/jam)	Xi	ρi (gr/L)	ρcampuran (gr/mL)
Benzen	0,0107	0,000236378	61,88899934	1,46292E-05
Toluen	45,2558	0,999763622	72,99728127	0,072980026
	45,2665			0,072994656

Vm = $Kv\sqrt{\frac{\rho L - \rho G}{\rho G}}$ = 0,166081015 ft/s

Kecepatan alir maksimum :

Vm = 0,166081015 ft/s

Kecepatan alir aktual :

V aktual = 0,132864812 ft/s

Diameter kolom bawah :

D bawah = $\sqrt{\frac{4\ x\ Vr}{\pi\ x\ \rho gas\ atas\ x\ V\ aktual\ x\ 3600}}$

= 7,942395366 ft

= 2,422430587 m = 95,37133444 in

Maka diambil kolom distilasi yang jumlahnya paling besar yaitu

7,942395366 ft = 8 ft = 2,44 m

Tower diameter 8 ft

Tray spacing 24 in Peters, halaman 684

* Tebal kolom distilasi (ts)

Bahan : Stainless Steel SA 167 Grade 11 Tipe 316

(Appendix D halaman 342, Brownell and Young)

P = 1 atm = 14,6959 psi

1 atm = 14,6959 psi

P operasi = 1,1 atm = 16,16549 psi

ri = 47,68566722 in

ts = 0,176424064

f = 18750 psi (Brownell halaman 342)

Diambil tebal standar shell = E = 80%

= 0,8

0,1875 in C = 0,125 in/10 tahun(3/16)

(Tabel 5.6 brownell halaman 88)

Shell : t = 0,1875 in

* Tebal tutup kolom distilasi

OD = 96 in

Bentuk : Torispherical head (Flanged and dishead head)

(Brownell halaman 88)

icr = 5,875 in (5 7 / 8)

Bahan : Stainless Steel SA 167 Grade 11 Tipe 316

(Brownell Appendix D halaman 342) r = 96 in

OD = 95,74633444 in

ID = 95,37133444 in

Diambil diameter luar standar shell (Tabel 5.7. Brownell Young halaman 90) Head :

OD = 96 in

icr = 5,875 in (5 7 / 8)

r = 96 in

icr/r = 0,061197917

Berdasarkan brownell halaman 256-258 karena icr/r > 6%, maka persamaan yang digunakan berdasarkan

persamaan 7.76 dan 7.77 halaman 138

W = = 1,760582305

faktor intensifikasi stress untuk torispherical head

= 0,216083978 in

diambil tebal head standar = 0,25 in (1 / 4)

(Tabel 5.6 Brownell young)

* Tinggi penutup distilasi

Sf = 1,5 in

Tinggi head (Hh) = OA = th + b + sf

b = OD/4

= 25,75 in = 24 in

Tinggi head (Hh) = OA = 0,654049647 m

Jumlah plate total = Naktual = 79 plate

Jumlah plate = Naktual - 1 = 78 plate dalam kolom

Tray spacing = 24 in

Tinggi plate total dalam kolom = jumlah plate dalam kolom x tray spacing

= 1872 in

= 47,54877432 m

Tinggi penutup kolom = Hh = 0,654049647 m

Tinggi kolom distilasi = H = Tinggi plate total dalam kolom + (2 x Hh)

= 48,85687362 m

Dengan demikian direncanakan kolom distilasi dengan spesifikasi :

ID = 7,769640797 ft = 2,369740443 m

1 ft = 0,305 m

OD = 7,942395366 f = 2,422430587 m

1 in = 0,0254 m

Tebal kolom (ts) = 0,1875 in = 0,0047625 m

Tebal penutup (th) = 0,25 in = 0,00635 m

Tray spacing = 24 in = 0,6096 m
Tinggi penutup (Hh) = 0,654049647 in = 0,016612861 m
Tinggi kolom (H) = 48,85687362 m = 48,85687362 m
Jumlah plate = 78 = 86
Bentuk head = Torispherical head (Flanged and dishead head)
Bahan = Stainless Steel SA 167 Grade 11 Tipe 316