LAMPIRAN A

REAKTOR

Tugas : Tempat berlangsungnya reaksi antara *Ethylene Cyanohydrin* dan Air untuk membentuk *Acrylonitrile*

Bentuk : Reaktor Fixed Bed Multitube

Fase : Gas

Tekanan : 2 atm. Suhu : 350 – 450°C

Katalis : Alumina (Al_2O_3)

A. Uraian proses

Reaksi *Ethylen Cyanohidrin* menjadi *Acrylonitrile* dan air terjadi pada suhu 450°C dengan katalis padat alumina. Reaksi terjadi pada permukaan padatan katalis sedangkan reaktan masuk reaktor pada fase gas. Kondisi operasi reaktor ini adalah *non-isothermal*, *adiabatis*, suhu gas 450°C dan tekanan 2 atm. Konversi reaktan menjadi *Acrylonitrile* sebesar 98%.

B. Menyusun Persamaan Reaksi :

Ditinjau reaksi :

$$C_3H_5ON\ (g) \rightleftharpoons C_3H_3N\ (g) + H_2O$$

A B C

Reaksi Pembentukan *Acrylonitrile* dirumuskan

sebagai : $(-r_A) = k\ (P_A)$

(Leidler, 1980)

P_A = konsentrasi keluar C_3H_5ON reactor

k = konstanta kinetika reaksi pembentukan *Acrylonitrile*

Reaksi berjalan pada suhu 350°C - 450°C hingga reaksi berjalan searah menjadi *Acrylonitrile* dan air.

(Ullman, 1985)

Harga konstanta kecepatan reaksi (k)

log k = (14,29-(234,9/2,303RT)

(Journal of physical organic chemistry, 1999)

C. Menghitung neraca massa komponen pada reaktor.

Waktu operasi = 330 hari/tahun

Kapasitas = 25.000 ton/tahun

$$= \frac{25000\ ton}{tahun} x \frac{1000\ kg}{1\ ton} x \frac{1\ tahun}{330\ hari} x \frac{1\ hari}{24\ jam}$$

= 3156,5657 kg/jam

Perbandingan umpan masuk reaktor adalah

a. Umpan Masuk Reaktor

Tabel A-1. Massa umpan reaktor

Komponen	Kg/jam	fr.massa	Kgmol/jam
C_3H_5ON	4409,37	0,98	62,03
C_3H_3N	0,09	0,000	0,001
H_2O	67,54	0,02	3,74
Jumlah	**4477,01**	**1,0000**	**65,78**

b. Reaksi

Reaksi yang terjadi merupakan reaksi searah dengan konversi 98 %. Secara stoikiometri.

		C_3H_5ON	C_3H_3N	+	H_2O
Mula	:	62,03	0,001		3,74
Reaksi	:	60,79	60,79		60,79
Sisa	:	1,24	60,79		64,54

Tabel A-2. Komposisi gas keluar reaktor

komponen	**Kg/jam**	**fr.massa**	**kgmol**
C_3H_5ON	88,18	0,01	1,24
H_2O	1163,03	0,25	64,54
C_3H_3N	3225,78	0,72	60,79
Jumlah	**4477,01**	**1,00**	**126,57**

c. Menghitung Neraca Massa Komponen pada Reaktor.

Menghitung panas reaksi

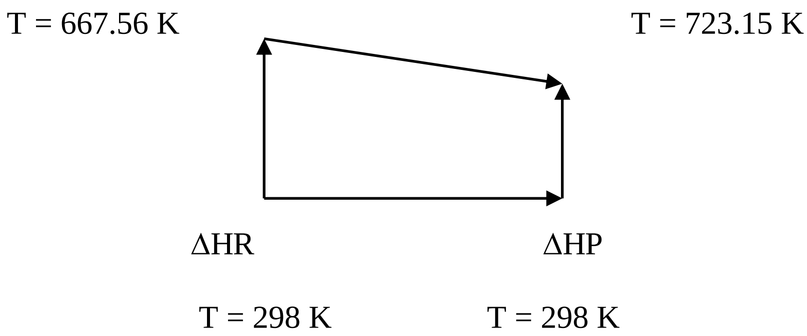
$$Q = \Delta H°R + \Delta H_R 298\ K + \Delta H°P$$

Keterangan : Q = panas reaksi total

$\Delta H°R$ = panas gas masuk reaktor

$\Delta H°P$ = panas gas keluar reaktor

$\Delta H_R°298$ = panas reaksi standar pada 298 K



Tabel A-3 Data ΔHf untuk masing masing komponen pada 298 K

Komponen	**ΔHf (kJ/mol)**	**ΔHf (kJ/kmol)**
C_3H_5ON	-98.3	-98300
H_2O	184.93	184930
C_3H_3N	-241.8	-241800

$\Delta H_R^o\ 298 \quad = \Delta H^oP \quad - \quad \Delta H^oR$

$\qquad = \Delta Hf\ C_3H_3N\ - (\Delta Hf\ C_3H_3N + \Delta Hf\ H_2O)$

$\qquad = -241800 - (184930 + -98300)$

$\qquad = 525030$ kJ/kmol

$\Delta H_R°298$ bernilai positif sehingga reaksi ini bersifat endotermis

d. Menentukan Jenis Reaktor

Dipilih reaktor jenis *fixed bed multitube* dengan pertimbangan sebagai berikut:

1. Reaksi yang berlangsung adalah fase gas dengan katalis padat.
2. Menggunakan katalis alumina yang dapat digunakan berulang-ulang.
4. *Pressure Drop* gas pada *fixed bed* lebih kecil dibandingkan dengan reaktor *fluidized bed*.

5. Kehilangan katalis termasuk kecil jika dibandingkan dengan reactor *fluidized bed*.
6. Tidak perlu pemisahan katalis dari gas keluaran reaktor.
7. Konstruksi reaktor lebih sederhana jika dibandingkan dengan reaktor *fluidized bed* sehingga biaya pembuatan, operasional, dan perawatannya relatif murah.

(Charles G Hill, p 425-431)

Kondisi operasi reaktor :

a. Non isotermal dan non adiabatis
b. P = 2 atm
c. T = 450°C

e. Menentukan Kondisi Umpan

Kondisi campuran gas yang bereaksi di dalam reaktor setiap saat mengalami perubahan untuk tiap increment panjang reaktor. Persamaan yang digunakan untuk menghitung kondisi campuran gas tersebut adalah sebagai berikut :

1. Menghitung berat molekul umpan

Berat molekul umpan merupakan berat molekul campuran gas yang dapat dihitung dengan persamaan :

$$BM\ campuran = \Sigma\ (Bmi.yi)$$

Dengan :

BMi = berat molekul komponen i, kg/kmol

yi = fraksi mol gas i

Tabel A-4. Fraksi mol gas campuran

Komponen	BMi (kg/kmol)	Massa (kg/jam)	Mol (kmol/jam)	yi	yi.BMi
C_3H_5ON	71.08	4409.37	62.03	0.94	67.02
H_2O	18.02	67.54	3.74	0.05	1.02
C_3H_3N	53.06	0.09	0.001	0.00	0.0015
Total		**4477.01**	**65.78**	**1.0000**	**68.05**

Diperoleh Bm_{avg} umpan = 68.05 kg/kmol

2. Menghitung volume reaktor dan densitas umpan

$$PV = nRT$$

n =	65.78	kmol/jam	=	18.27	mol/dtk
R =	82.05	atm.cm3/mol.0K	=	0.0820567	
P =	2	atm	=	29,4	psi
T =	450	^0C	=	723.15	K

$$V = \frac{nRT}{P} = \frac{65.78 \text{ x } 0.0820567 \text{ x } 723.15}{2} = 1951.78 \text{cm}^3/\text{detik}$$

$$\rho = \frac{P.BM}{RT}$$

ρ = 2.29 gr/cm3 = 2295.38 kg/m3

3. Menghitung viskositas umpan µ

Untuk menghitung viskositas umpan digunakan persamaan yang diperoleh dari Yaws, 1999, yaitu $\mu i = A + BT + CT^2$

μgi = viskositas gas, mikropoise

T = suhu umpan, K

Tabel A-5. Konstanta viskositas gas

Komponen	A	B	C
C_3H_5ON	0	0	0
C_3H_3O	-4.783	2.40E-01	-1.45E-05
H_2O	-36.626	4.29E-01	-1.62E-05

Tabel A-6. Viskositas gas

Komponen	**Yi**	**μ gas (micropoise)**
C_3H_5ON	9.85E-01	0
C_3H_3N	2.16E-05	161.48
H_2O	1.51E-02	265.07
Total	**1.0000**	**426.55**

Tabel A-7. Viskositas gas campuran

Komponen	**$yi.\mu_{gas}$**	**$yi.\mu_{gas}$**
	(micropoise)	**(kg/m.s)**
C_3H_5ON	0.00E+00	0.04
C_3H_3N	1.34E-07	0.74
H_2O	5.69E-05	0.0018
Total	**5.70E-05**	**0.0018**

μgi campuran = 0.00175 kg/m.s

4. Menghitung konduktivitas panas umpan (K_G)

   K_G dihitung menggunakan persamaan dari Yaws, 1999, yaitu :

$K_G = A + BT + CT^2$

K_G = konduktivitas gas, W/m.K

T = suhu umpan, K

K_G = $\Sigma(K_G.xi)$

Tabel A-8. Konstanta konduktivitas gas

Komponen	**A**	**B**	**C**
C_3H_5ON	0	0	0
C_3H_3N	0.01204	-0.000049047	1.4193E-07
H_2O	0.00053	0.000047093	4.9551E-08

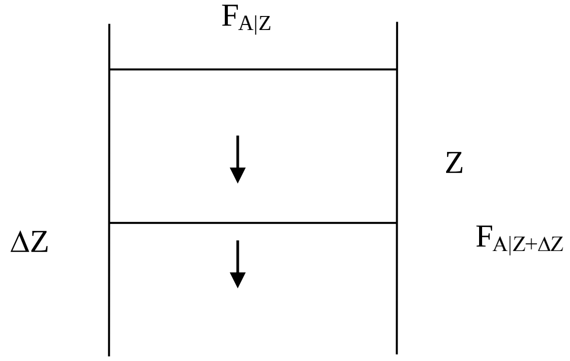
Tabel A-9 Konduktivitas gas campuran

Komponen	**yi**	**k_{gas}**	**$yi.k_{gas}$**
		W/m.K	**W/m.K**
CO	9.85E-01	0	1.09743E-06
Cl_2	2.16E-05	0.050769946	0.000912443
$COCl_2$	1.51E-02	0.060479984	0.000913541
Total	1.0000	0.11124993	1.09743E-06

k campuran = 0.000913 W/m.K
= 0.00328 kJ/jam.m.K

f. Penyusunan Model Matematis

1. Neraca massa pada elemen volume tube



Rate of in – out – reaksi = acc

$$F_{A|Z} - F_{A|Z+\Delta Z} - r.\Delta W = 0$$

$$F_{A|Z} - F_{A|Z+\Delta Z} = r.\Delta V.\rho_b$$

$$F_{A|Z+\Delta Z} - F_{A|Z} = -r.A.\Delta Z.\rho_b$$

$$\lim_{\Delta Z \to 0} \frac{F_{A|Z+\Delta Z} - F_{A|Z}}{\Delta Z} = -r.\frac{\pi}{4}.IDT^2.\rho_b$$

$$\frac{dF_A}{dZ} = -r.\frac{\pi}{4}.IDT^2.\rho_b$$

$$-F_{A0}.\frac{dX_A}{dZ} = -r.\frac{\pi}{4}.IDT^2.\rho_b$$

$$\frac{dX_A}{dZ} = \frac{r.\pi.IDT^2.\rho_b}{4.F_{A0}}$$

Untuk N_T buah *tube*:

$$\frac{dX_A}{dZ} = \frac{r.\pi.IDT^2.\rho_b}{4.F_{A0}}.N_T$$

Reaksi untuk $\frac{dX_A}{dZ}$, sehingga:

$$\frac{dX_A}{dZ} = \frac{r.\pi.IDT^2.\rho_b}{4.F_{A0}}.N_T$$

Kondisi Batas:

Pada saat, Z = 0 $X_A = X_0 = 0$

Z = H $X_A = X = 0{,}98$

$\frac{dX_A}{dZ}$: perubahan konversi *Acrylonitrile* tiap *increment* panjang reaktor

r : laju reaksi, kmol/m3/jam

ρ_b : bulk density katalis, kg/m3

F_{A0} : laju alir mol mula-mula C_3H_3ON, kmol/jam

g. Menentukan jenis dan ukuran tube

Dari hasil perhitungan, maka dipilih ukuran pipa standart :

Ukuran tube ditentukan dengan cara memilih pada table 10, Apendix D.Q Kern halaman 843 dengan spesifikasi sebagai berikut :

Ukuran pipa (IPS)	=	1.25	in	3.175	cm
OD	=	1.61	in	4.0894	cm
ID	=	1.9	in	4.826	cm
Flow area per pipe	=	2.01	in2	12.9677	cm2
Schedule number	=	40			
Surface per lin ft	=	0.435	ft2/ft	*(Kern, 889)*	

Re shell : 46204.02

Menghitung kecepatan massa per satuan luas tube

Gs : 1026115.79 kg/m^{2}jam

Re tube : 1367.76

Menghitung kecepatan massa per satuan luas tube

Gt : 3452428 kg/m^{2}jam

Mencari luas penampang total (At)

$$At = \frac{Gs}{Gt} = 2888.095 \text{ cm}^2 = 0.288 \text{ m}^2$$

Nt : 220 buah trial

h. Menentukan diameter shell dan jumlah tube

Menghitung bilangan Reynold di shell (Res)

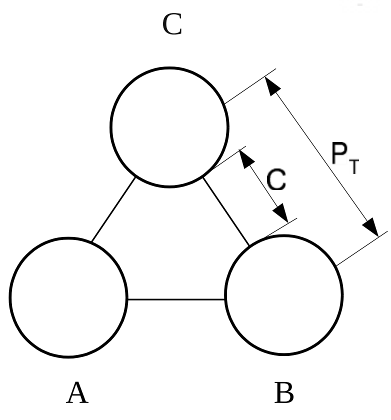
IDs	=	diameter dalam shell	=	36.8713	in
B	=	baffle spacing (0.25*IDs) kern,1965	=	9.2178	in
PT	=	pitch tube	=	2.375	in
C'	=	jarak antar tube (clearance)	=	0.475	in
Ws	=	laju aliran pemanas	=	21620.34	kg/jam

i. Menentukan susunan tube

Direncanakan tube disusun dengan pola triangular pitch, dengan alasan :

1. Turbulensi yang terjadi pada susunan segitiga sama sisi lebih besar dibandingkan dengan susunan bujur sangkar, karena fluida yang mengalir di antara pipa yang letaknya berdekatan akan langsung menumbuk pipa yang terletak pada deretan berikutnya.
2. Koefisien perpindahan panas konveksi (h) pada susunan segitiga 25% lebih tinggi dibandingkan dengan fluida yang mengalir dalam shell pada susunan segi empat.

(Agra, S.W.,Perpindahan Panas, p 7-73)



Susunan tube = triangular

Pitch tube (PT)= 1.25 x ODt = 2.075 in = 5.2705 cm

Clearance (C') = PT - ODt = 3.6105 in = 9.1707 cm

untuk menghitung diameter shell, dicari luas penampang shell total (A total)

luas shell = Luas segitiga

$$\frac{\pi}{4} xIDs^2 = 2 \cdot Nt \cdot \left(\frac{1}{2} \cdot Pt^2 \cdot \sin 60 \right)$$

$$\frac{\pi}{4} xIDs^2 = 2 \cdot Nt \cdot \left(\frac{1}{2} \cdot Pt^2 \cdot 0.866 \right)$$

$$IDs = \sqrt{\frac{4 \cdot Nt \cdot P_T^2 \cdot 0.866}{\pi}}$$

= 93.6532 cm

= 36.8713 in

Menentukan Jenis Pemanas

Jenis : Superheated Steam

Suhu : 454.4°C

ʎsteam : 1457.5 kJ/kg

Menentukan jumlah pendingin yang dibutuhkan

$$Wp = \frac{Q_h}{\lambda_{steam}}$$

Menghitung Panjang Reaktor

Persaamaan – persamaan yang digunakan untuk menentukan panjang reactor :

Persamaan neraca massa pada elemen volume:

$$\frac{dx}{dz} = \frac{(-ra).Nt.\frac{\pi}{4}.IDt^2.\rho.(1-\varepsilon)}{F_{A0}}$$

Persamaan neraca panas pada elemen volume :

$$\frac{dT}{dz} = \frac{(\Delta Hf).(-ra).Nt.\frac{\pi}{4}.IDt^2.\rho.(1-\varepsilon) + U.(T-Ts).\pi.ODt}{\sum(Fi-Cpi)}$$

Persamaan neraca panas pendingin :

$$\frac{dTs}{dz} = -\frac{U.(T-Ts).\pi.ODt.Nt}{Ws.Cps}$$

Persamaan pressure drop

$$\frac{dP}{dz} = -\frac{Gt}{IDt.\rho}\frac{(1-\varepsilon)}{\varepsilon^3}\left[\frac{150.(1-\varepsilon)}{Dp.\frac{Gt}{\mu.camp}} + 1.75\right]$$

Persamaan-persamaan diferensial diatas diselesaikan secara simultan menggunakan metode Runge Kutta orde 4. Perhitungan dihentikan ketika konversi sudah mencapai 98%.

Tabel A-11. Hasil data iterasi reaktor

Δz	0.0500						
z (m)	**x**	**T (K)**	**Ts (K)**	**dx/dz**	**dT/dz**	**dTs/dz**	**dP/dz**
0	0.0000	723.0000	473.0000	0.0061	-0.4881	3.0530	-46460362.2432
	0.0614	718.1190	503.5305	0.0047	-0.3967	2.6327	-46146649.5990
	0.1085	714.1524	529.8574	0.0038	-0.3306	2.2696	-45891706.3327
	0.1464	710.8461	552.5530	0.0031	-0.2803	1.9555	-45679200.2094
0.05	0.0876	715.5900	522.3768	0.0041	-0.3517	2.3761	-45984102.8985
	0.1286	712.0726	546.1382	0.0034	-0.2966	2.0475	-45758029.2009
	0.1623	709.1068	566.6132	0.0029	-0.2535	1.7632	-45567410.6681
	0.1909	706.5714	584.2455	0.0025	-0.2190	1.5173	-45404452.6539
0.10	0.1511	710.0199	560.7600	0.0030	-0.2660	1.8454	-45626098.0570
	0.1811	707.3596	579.2135	0.0026	-0.2291	1.5883	-45455117.3314
	0.2070	705.0684	595.0969	0.0023	-0.1992	1.3661	-45307850.9754
	0.2298	703.0768	608.7576	0.0020	-0.1744	1.1739	-45179852.1840
0.15	0.2003	705.6965	590.5201	0.0024	-0.2074	1.4299	-45348225.4963
	0.2238	703.6223	604.8187	0.0021	-0.1813	1.2290	-45214908.3527
	0.2448	701.8095	617.1091	0.0019	-0.1595	1.0554	-45098396.8368
	0.2637	700.2142	627.6636	0.0017	-0.1413	0.9054	-44995862.3227
0.20	0.2404	702.2621	613.5343	0.0019	-0.1654	1.1051	-45127488.0782
	0.2598	700.6085	624.5858	0.0018	-0.1462	0.9484	-45021205.6527
	0.2774	699.1467	634.0699	0.0016	-0.1300	0.8130	-44927253.2613
	0.2936	697.8468	642.1998	0.0015	-0.1162	0.6961	-44843705.9832
0.25	0.2744	699.4823	631.2811	0.0017	-0.1342	0.8518	-44948823.0686
	0.2909	698.1399	639.7986	0.0015	-0.1199	0.7296	-44862541.9078
	0.3062	696.9413	647.0942	0.0014	-0.1076	0.6241	-44785511.1779
	0.3205	695.8655	653.3348	0.0013	-0.0971	0.5330	-44716363.7506
0.30	0.3041	697.1949	644.9211	0.0014	-0.1108	0.6543	-44801810.6059
	0.3185	696.0874	651.4639	0.0014	-0.0998	0.5591	-44730627.5270
	0.3321	695.0895	657.0551	0.0013	-0.0904	0.4770	-44666492.3168

Tabel A-11. Hasil data iterasi reaktor (lanjutan)

Δz	0.0500						
z (m)	**x**	**T (K)**	**Ts (K)**	**dx/dz**	**dT/dz**	**dTs/dz**	**dP/dz**
	0.3449	694.1858	661.8254	0.0012	-0.0823	0.4062	-44608406.6478
0.35	0.3305	695.2838	655.3637	0.0013	-0.0928	0.5006	-44678977.2274
	0.3435	694.3562	660.3695	0.0012	-0.0843	0.4266	-44619356.0794
	0.3557	693.5130	664.6351	0.0012	-0.0770	0.3627	-44565166.8816
	0.3674	692.7429	668.2625	0.0011	-0.0707	0.3077	-44515666.9043
0.40	0.3545	693.6634	663.3201	0.0012	-0.0788	0.3811	-44574830.6885
	0.3663	692.8750	667.1310	0.0011	-0.0723	0.3236	-44524162.5684
	0.3775	692.1524	670.3667	0.0011	-0.0666	0.2740	-44477720.1660
	0.3883	691.4869	673.1068	0.0010	-0.0616	0.2313	-44434943.7084
0.45	0.3765	692.2699	669.3454	0.0011	-0.0679	0.2883	-44485266.2153
	0.3874	691.5904	672.2284	0.0010	-0.0628	0.2437	-44441595.7895
	0.3978	690.9625	674.6650	0.0010	-0.0583	0.2052	-44401239.5981
	0.4078	690.3795	676.7172	0.0010	-0.0544	0.1721	-44363771.7900
0.50	0.3970	691.0549	673.8727	0.0010	-0.0594	0.2163	-44407178.7651
	0.4071	690.4612	676.0361	0.0010	-0.0553	0.1817	-44369023.8512
	0.4168	689.9084	677.8535	0.0009	-0.0517	0.1520	-44333488.1937
	0.4263	689.3911	679.3730	0.0009	-0.0486	0.1263	-44300245.5222
0.55	0.4162	689.9816	677.2396	0.0009	-0.0525	0.1606	-44338198.2725
	0.4257	689.4562	678.8456	0.0009	-0.0493	0.1338	-44304425.7365
	0.4349	688.9632	680.1837	0.0009	-0.0464	0.1108	-44272738.8668
	0.4438	688.4987	681.2913	0.0009	-0.0439	0.0910	-44242886.2764
0.60	0.4343	689.0217	679.7087	0.0009	-0.0471	0.1175	-44276502.8419
	0.4433	688.5509	680.8836	0.0009	-0.0445	0.0968	-44246240.5426
	0.4520	688.1061	681.8513	0.0008	-0.0422	0.0790	-44217651.9080
	0.4604	687.6843	682.6411	0.0008	-0.0401	0.0637	-44190542.3276
0.65	0.4515	688.1532	681.4844	0.0008	-0.0427	0.0842	-44220683.7405
	0.4600	687.7265	682.3264	0.0008	-0.0406	0.0682	-44193256.6242
	0.4683	687.3208	683.0085	0.0008	-0.0387	0.0545	-44167183.4983
	0.4763	686.9339	683.5535	0.0008	-0.0370	0.0427	-44142313.0691
0.70	0.4679	687.3591	682.7255	0.0008	-0.0391	0.0586	-44169646.1014
	0.4760	686.9683	683.3111	0.0008	-0.0374	0.0462	-44144529.0504
	0.4839	686.5947	683.7734	0.0008	-0.0358	0.0357	-44120516.8469
	0.4916	686.2365	684.1302	0.0008	-0.0344	0.0266	-44097491.4039
0.75	0.4835	686.6261	683.5556	0.0008	-0.0361	0.0388	-44122534.9398
	0.4913	686.2649	683.9439	0.0008	-0.0347	0.0294	-44099317.5590

Tabel A-11. Hasil data iterasi reaktor (lanjutan)

Δz	0.0500						
z (m)	**x**	**T (K)**	**Ts (K)**	**dx/dz**	**dT/dz**	**dTs/dz**	**dP/dz**
	0.4989	685.9178	684.2375	0.0007	-0.0334	0.0213	-44077010.0189
	0.5063	685.5834	684.4501	0.0007	-0.0323	0.0143	-44055519.7882
0.80	0.4985	685.9438	684.0703	0.0007	-0.0337	0.0237	-44078679.4976
	0.5060	685.6071	684.3074	0.0007	-0.0325	0.0165	-44057039.5766
	0.5133	685.2822	684.4719	0.0007	-0.0314	0.0103	-44036156.2033
	0.5204	684.9679	684.5745	0.0007	-0.0305	0.0050	-44015956.5775
0.85	0.5130	685.3039	684.3440	0.0007	-0.0316	0.0122	-44037551.0696
	0.5202	684.9878	684.4656	0.0007	-0.0306	0.0066	-44017234.4452
	0.5272	684.6815	684.5317	0.0007	-0.0297	0.0019	-43997553.3242
	0.5341	684.3843	684.5507	0.0007	-0.0289	-0.0021	-43978450.1842
0.90	0.5269	684.6999	684.4343	0.0007	-0.0299	0.0034	-43998730.8659
	0.5338	684.4012	684.4679	0.0007	-0.0290	-0.0008	-43979536.0603
	0.5406	684.1110	684.4595	0.0007	-0.0283	-0.0044	-43960880.7194
	0.5473	683.8284	684.4153	0.0007	-0.0276	-0.0074	-43942719.1813
0.95	0.5404	684.1266	684.3856	0.0007	-0.0284	-0.0033	-43961885.4135
	0.5470	683.8429	684.3528	0.0007	-0.0276	-0.0065	-43943651.8667
	0.5536	683.5664	684.2881	0.0006	-0.0270	-0.0092	-43925881.1891
	0.5600	683.2965	684.1966	0.0006	-0.0264	-0.0114	-43908536.9494
1.00	0.5534	683.5799	684.2325	0.0006	-0.0271	-0.0083	-43926747.6624
	0.5598	683.3091	684.1497	0.0006	-0.0264	-0.0107	-43909346.6863
	0.5662	683.0446	684.0431	0.0006	-0.0259	-0.0127	-43892347.1433
	0.5724	682.7859	683.9164	0.0006	-0.0253	-0.0143	-43875719.8043
1.05	0.5660	683.0564	684.0015	0.0006	-0.0259	-0.0120	-43893102.4281
	0.5722	682.7970	683.8816	0.0006	-0.0254	-0.0138	-43876430.2336
	0.5784	682.5431	683.7439	0.0006	-0.0249	-0.0152	-43860109.8886
	0.5845	682.2942	683.5914	0.0006	-0.0244	-0.0165	-43844117.7975
1.10	0.5782	682.5534	683.7132	0.0006	-0.0249	-0.0147	-43860775.1478
	0.5843	682.3040	683.5659	0.0006	-0.0245	-0.0160	-43844747.4568
	0.5902	682.0595	683.4057	0.0006	-0.0240	-0.0171	-43829031.3248
	0.5961	681.8195	683.2347	0.0006	-0.0236	-0.0180	-43813607.5752
1.15	0.5901	682.0687	683.3833	0.0006	-0.0240	-0.0167	-43829623.1762
	0.5960	681.8283	683.2164	0.0006	-0.0236	-0.0176	-43814171.0476
	0.6018	681.5922	683.0400	0.0006	-0.0232	-0.0184	-43798997.4969
	0.6075	681.3602	682.8560	0.0006	-0.0228	-0.0190	-43784086.8242

Tabel A-11. Hasil data iterasi reaktor (lanjutan)

Δz	0.0500						
z (m)	**x**	**T (K)**	**Ts (K)**	**dx/dz**	**dT/dz**	**dTs/dz**	**dP/dz**
1.20	0.6016	681.6005	683.0241	0.0006	-0.0232	-0.0181	-43799529.0316
	0.6073	681.3681	682.8432	0.0006	-0.0228	-0.0187	-43784595.6224
	0.6130	681.1397	682.6557	0.0006	-0.0225	-0.0193	-43769913.5784
	0.6185	680.9150	682.4630	0.0005	-0.0221	-0.0197	-43755469.9439
1.25	0.6128	681.1472	682.6447	0.0006	-0.0225	-0.0190	-43770395.1456
	0.6184	680.9222	682.4543	0.0005	-0.0221	-0.0195	-43755933.1918
	0.6239	680.7007	682.2595	0.0005	-0.0218	-0.0198	-43741699.9598
	0.6293	680.4827	682.0612	0.0005	-0.0215	-0.0201	-43727684.6674
1.30	0.6237	680.7076	682.2522	0.0005	-0.0218	-0.0196	-43742139.7728
	0.6291	680.4893	682.0558	0.0005	-0.0215	-0.0199	-43728109.6263
	0.6345	680.2742	681.8565	0.0005	-0.0212	-0.0201	-43714289.1922
	0.6398	680.0623	681.6552	0.0005	-0.0209	-0.0203	-43700669.4173
1.35	0.6343	680.2805	681.8521	0.0005	-0.0212	-0.0200	-43714693.7976
	0.6396	680.0684	681.6521	0.0005	-0.0209	-0.0202	-43701061.8931
	0.6448	679.8593	681.4506	0.0005	-0.0206	-0.0203	-43687623.5952
	0.6500	679.6532	681.2480	0.0005	-0.0203	-0.0203	-43674371.2318
1.40	0.6447	679.8652	681.4483	0.0005	-0.0206	-0.0202	-43687998.2361
	0.6499	679.6588	681.2468	0.0005	-0.0204	-0.0202	-43674735.8910
	0.6549	679.4553	681.0446	0.0005	-0.0201	-0.0202	-43661653.3782
	0.6600	679.2544	680.8422	0.0005	-0.0198	-0.0202	-43648744.1346
1.45	0.6548	679.4607	681.0440	0.0005	-0.0201	-0.0202	-43662002.2759
	0.6598	679.2597	680.8424	0.0005	-0.0198	-0.0202	-43649084.7490
	0.6648	679.0614	680.6408	0.0005	-0.0196	-0.0201	-43636335.1629
	0.6697	678.8655	680.4396	0.0005	-0.0193	-0.0201	-43623747.8494
1.50	0.6647	679.0664	680.6414	0.0005	-0.0196	-0.0201	-43636661.7356
	0.6696	678.8705	680.4408	0.0005	-0.0194	-0.0200	-43624067.4868
	0.6744	678.6770	680.2407	0.0005	-0.0191	-0.0199	-43611630.8162
	0.6792	678.4858	680.0414	0.0005	-0.0189	-0.0198	-43599346.7833
1.55	0.6743	678.6818	680.2422	0.0005	-0.0191	-0.0199	-43611937.8498
	0.6791	678.4905	680.0433	0.0005	-0.0189	-0.0198	-43599647.9552
	0.6838	678.3016	679.8454	0.0005	-0.0187	-0.0197	-43587506.5272
	0.6885	678.1150	679.6486	0.0005	-0.0184	-0.0196	-43575509.2197
1.60	0.6837	678.3061	679.8476	0.0005	-0.0187	-0.0197	-43587796.3075
	0.6884	678.1194	679.6511	0.0005	-0.0185	-0.0195	-43575793.9975
	0.6930	677.9348	679.4557	0.0005	-0.0182	-0.0194	-43563932.0725

Tabel A-11. Hasil data iterasi reaktor (lanjutan)

Δz	0.0500						
z (m)	**x**	**T (K)**	**Ts (K)**	**dx/dz**	**dT/dz**	**dTs/dz**	**dP/dz**
	0.6976	677.7524	679.2618	0.0005	-0.0180	-0.0193	-43552206.6759
1.65	0.6929	677.9391	679.4584	0.0005	-0.0183	-0.0194	-43564206.4889
	0.6975	677.7566	679.2646	0.0005	-0.0180	-0.0192	-43552476.7809
	0.7020	677.5762	679.0722	0.0004	-0.0178	-0.0191	-43540880.2310
	0.7065	677.3977	678.8814	0.0004	-0.0176	-0.0189	-43529413.3886
1.70	0.7019	677.5802	679.0752	0.0004	-0.0178	-0.0191	-43541140.8573
	0.7064	677.4017	678.8845	0.0004	-0.0177	-0.0189	-43529670.2628
	0.7108	677.2252	678.6953	0.0004	-0.0175	-0.0188	-43518326.3142
	0.7152	677.0507	678.5077	0.0004	-0.0173	-0.0186	-43507105.9010
1.75	0.7107	677.2291	678.6984	0.0004	-0.0175	-0.0188	-43518574.4724
	0.7151	677.0545	678.5109	0.0004	-0.0173	-0.0186	-43507350.7620
	0.7195	676.8817	678.3250	0.0004	-0.0171	-0.0184	-43496247.7887
	0.7237	676.7108	678.1407	0.0004	-0.0169	-0.0183	-43485262.7282
1.80	0.7194	676.8854	678.3283	0.0004	-0.0171	-0.0184	-43496484.5982
	0.7236	676.7144	678.1441	0.0004	-0.0169	-0.0183	-43485496.6135
	0.7279	676.5453	677.9615	0.0004	-0.0167	-0.0181	-43474623.9699
	0.7321	676.3779	677.7806	0.0004	-0.0166	-0.0179	-43463864.0866
1.85	0.7278	676.5488	677.9649	0.0004	-0.0167	-0.0181	-43474850.3866
	0.7320	676.3813	677.7840	0.0004	-0.0166	-0.0179	-43464087.8872
	0.7362	676.2156	677.6049	0.0004	-0.0164	-0.0177	-43453435.7728
	0.7403	676.0516	677.4274	0.0004	-0.0162	-0.0176	-43442891.6716
1.90	0.7361	676.2190	677.6082	0.0004	-0.0164	-0.0177	-43453652.6203
	0.7402	676.0549	677.4307	0.0004	-0.0162	-0.0176	-43443106.1594
	0.7443	675.8924	677.2550	0.0004	-0.0161	-0.0174	-43432665.5080
	0.7483	675.7316	677.0808	0.0004	-0.0159	-0.0172	-43422328.4752
1.95	0.7442	675.8957	677.2583	0.0004	-0.0161	-0.0174	-43432873.5016
	0.7482	675.7348	677.0842	0.0004	-0.0159	-0.0172	-43422534.3243
	0.7522	675.5755	676.9117	0.0004	-0.0158	-0.0171	-43412296.7131
	0.7562	675.4178	676.7409	0.0004	-0.0156	-0.0169	-43402158.6349
2.00	0.7521	675.5786	676.9150	0.0004	-0.0158	-0.0171	-43412496.4792
	0.7561	675.4209	676.7442	0.0004	-0.0156	-0.0169	-43402356.4388
	0.7600	675.2646	676.5750	0.0004	-0.0155	-0.0168	-43392314.0130
	0.7639	675.1099	676.4074	0.0004	-0.0153	-0.0166	-43382367.3073
2.05	0.7599	675.2676	676.5783	0.0004	-0.0155	-0.0168	-43392506.1045
	0.7638	675.1128	676.4107	0.0004	-0.0153	-0.0166	-43382557.5924

Tabel A-11. Hasil data iterasi reaktor (lanjutan)

∆z	0.0500						
z (m)	**x**	**T (K)**	**Ts (K)**	**dx/dz**	**dT/dz**	**dTs/dz**	**dP/dz**
	0.7677	674.9595	676.2447	0.0004	-0.0152	-0.0164	-43372703.0022
	0.7715	674.8076	676.0803	0.0004	-0.0150	-0.0163	-43362940.5624
2.10	0.7676	674.9624	676.2479	0.0004	-0.0152	-0.0164	-43372887.9107
	0.7714	674.8104	676.0834	0.0004	-0.0151	-0.0163	-43363123.7988
	0.7752	674.6599	675.9206	0.0004	-0.0149	-0.0161	-43353450.1469
	0.7789	674.5108	675.7593	0.0004	-0.0148	-0.0160	-43343865.2932
2.15	0.7751	674.6627	675.9237	0.0004	-0.0149	-0.0161	-43353628.3126
	0.7788	674.5135	675.7624	0.0004	-0.0148	-0.0160	-43344041.9036
	0.7825	674.3657	675.6026	0.0004	-0.0146	-0.0158	-43334542.7001
	0.7862	674.2193	675.4443	0.0004	-0.0145	-0.0157	-43325129.1391
2.20	0.7825	674.3684	675.6056	0.0004	-0.0146	-0.0158	-43334714.5196
	0.7861	674.2219	675.4473	0.0004	-0.0145	-0.0157	-43325299.5058
	0.7898	674.0767	675.2904	0.0004	-0.0144	-0.0155	-43315968.6306
	0.7934	673.9329	675.1350	0.0004	-0.0143	-0.0154	-43306720.4199
2.25	0.7897	674.0793	675.2934	0.0004	-0.0144	-0.0155	-43316134.4634
	0.7933	673.9354	675.1379	0.0004	-0.0143	-0.0154	-43306884.8907
	0.7969	673.7928	674.9840	0.0004	-0.0141	-0.0153	-43297716.5600
	0.8004	673.6514	674.8314	0.0004	-0.0140	-0.0151	-43288628.0786
2.30	0.7968	673.7953	674.9868	0.0004	-0.0141	-0.0153	-43297876.7338
	0.8004	673.6538	674.8342	0.0004	-0.0140	-0.0151	-43288786.9712
	0.8039	673.5136	674.6831	0.0003	-0.0139	-0.0150	-43279775.7097
	0.8074	673.3746	674.5333	0.0003	-0.0138	-0.0148	-43270841.6308
2.35	0.8038	673.5160	674.6858	0.0003	-0.0139	-0.0150	-43279930.5244
	0.8073	673.3770	674.5360	0.0003	-0.0138	-0.0148	-43270995.2370
	0.8107	673.2392	674.3875	0.0003	-0.0137	-0.0147	-43262135.8529
	0.8142	673.1025	674.2404	0.0003	-0.0136	-0.0146	-43253351.1215
2.40	0.8107	673.2415	674.3902	0.0003	-0.0137	-0.0147	-43262285.5843
	0.8141	673.1048	674.2430	0.0003	-0.0136	-0.0146	-43253499.7101
	0.8175	672.9692	674.0972	0.0003	-0.0134	-0.0145	-43244787.2730
	0.8209	672.8348	673.9526	0.0003	-0.0133	-0.0143	-43236147.0852
2.45	0.8174	672.9715	674.0998	0.0003	-0.0134	-0.0145	-43244932.1759
	0.8208	672.8370	673.9552	0.0003	-0.0133	-0.0143	-43236290.9051
	0.8241	672.7037	673.8119	0.0003	-0.0132	-0.0142	-43227720.7270
	0.8275	672.5714	673.6698	0.0003	-0.0131	-0.0141	-43219220.5120
2.50	0.8241	672.7059	673.8144	0.0003	-0.0132	-0.0142	-43227861.0373

Tabel A-11. Hasil data iterasi reaktor (lanjutan)

Δz	0.0500						
z (m)	**x**	**T (K)**	**Ts (K)**	**dx/dz**	**dT/dz**	**dTs/dz**	**dP/dz**
	0.8274	672.5736	673.6723	0.0003	-0.0131	-0.0141	-43219359.7940
	0.8307	672.4424	673.5314	0.0003	-0.0130	-0.0140	-43210927.4120
	0.8339	672.3123	673.3918	0.0003	-0.0129	-0.0138	-43202562.8156
2.55	0.8306	672.4445	673.5339	0.0003	-0.0130	-0.0140	-43211063.3488
	0.8339	672.3144	673.3942	0.0003	-0.0129	-0.0138	-43202697.7747
	0.8371	672.1852	673.2557	0.0003	-0.0128	-0.0137	-43194398.9356
	0.8403	672.0571	673.1184	0.0003	-0.0127	-0.0136	-43186165.8062
2.60	0.8371	672.1873	673.2581	0.0003	-0.0128	-0.0137	-43194530.7033
	0.8403	672.0592	673.1207	0.0003	-0.0127	-0.0136	-43186296.6426
	0.8434	671.9321	672.9846	0.0003	-0.0126	-0.0135	-43178127.2890
	0.8466	671.8059	672.8495	0.0003	-0.0125	-0.0134	-43170021.6640
2.65	0.8434	671.9341	672.9869	0.0003	-0.0126	-0.0135	-43178255.0784
	0.8465	671.8079	672.8518	0.0003	-0.0125	-0.0134	-43170148.5653
	0.8497	671.6828	672.7178	0.0003	-0.0124	-0.0133	-43162104.8230
	0.8528	671.5586	672.5850	0.0003	-0.0123	-0.0132	-43154122.9170
2.70	0.8496	671.6847	672.7201	0.0003	-0.0124	-0.0133	-43162228.8127
	0.8527	671.5605	672.5872	0.0003	-0.0123	-0.0132	-43154246.0587
	0.8558	671.4372	672.4554	0.0003	-0.0122	-0.0131	-43146324.2253
	0.8589	671.3149	672.3248	0.0003	-0.0121	-0.0130	-43138462.4192
2.75	0.8558	671.4391	672.4576	0.0003	-0.0122	-0.0131	-43146444.5828
	0.8588	671.3168	672.3269	0.0003	-0.0121	-0.0130	-43138581.9661
	0.8619	671.1954	672.1972	0.0003	-0.0121	-0.0129	-43130778.5007
	0.8649	671.0749	672.0686	0.0003	-0.0120	-0.0128	-43123033.3317
2.80	0.8618	671.1972	672.1993	0.0003	-0.0121	-0.0129	-43130895.3833
	0.8648	671.0767	672.0706	0.0003	-0.0120	-0.0128	-43123149.4388
	0.8678	670.9570	671.9430	0.0003	-0.0119	-0.0127	-43115460.9520
	0.8708	670.8383	671.8164	0.0003	-0.0118	-0.0126	-43107829.1045
2.85	0.8678	670.9588	671.9450	0.0003	-0.0119	-0.0127	-43115574.5079
	0.8707	670.8400	671.8184	0.0003	-0.0118	-0.0126	-43107941.9177
	0.8737	670.7222	671.6927	0.0003	-0.0117	-0.0125	-43100365.1633
	0.8766	670.6051	671.5681	0.0003	-0.0116	-0.0124	-43092843.4604
2.90	0.8736	670.7239	671.6947	0.0003	-0.0117	-0.0125	-43100475.5319
	0.8766	670.6068	671.5700	0.0003	-0.0116	-0.0124	-43092953.1174
	0.8795	670.4906	671.4463	0.0003	-0.0115	-0.0123	-43085484.9839
	0.8823	670.3753	671.3235	0.0003	-0.0115	-0.0122	-43078070.3797

Tabel A-11. Hasil data iterasi reaktor (lanjutan)

Δz	0.0500						
z (m)	**x**	**T (K)**	**Ts (K)**	**dx/dz**	**dT/dz**	**dTs/dz**	**dP/dz**
2.95	0.8794	670.4923	671.4482	0.0003	-0.0115	-0.0123	-43085592.2970
	0.8823	670.3769	671.3254	0.0003	-0.0115	-0.0122	-43078177.0103
	0.8852	670.2624	671.2035	0.0003	-0.0114	-0.0121	-43070814.5137
	0.8880	670.1486	671.0826	0.0003	-0.0113	-0.0120	-43063504.0861
3.00	0.8851	670.2640	671.2054	0.0003	-0.0114	-0.0121	-43070918.8956
	0.8880	670.1502	671.0844	0.0003	-0.0113	-0.0120	-43063607.8129
	0.8908	670.0373	670.9643	0.0003	-0.0112	-0.0119	-43056348.0897
	0.8936	669.9251	670.8452	0.0003	-0.0111	-0.0118	-43049139.0335
3.05	0.8907	670.0389	670.9661	0.0003	-0.0112	-0.0119	-43056449.6580
	0.8935	669.9267	670.8470	0.0003	-0.0111	-0.0118	-43049239.9727
	0.8963	669.8153	670.7287	0.0003	-0.0111	-0.0117	-43042080.2732
	0.8991	669.7047	670.6112	0.0003	-0.0110	-0.0117	-43034969.8941
3.10	0.8963	669.8168	670.7304	0.0003	-0.0111	-0.0117	-43042179.1392
	0.8990	669.7062	670.6130	0.0003	-0.0110	-0.0117	-43035068.1557
	0.9018	669.5963	670.4964	0.0003	-0.0109	-0.0116	-43028005.8380
	0.9045	669.4872	670.3806	0.0003	-0.0108	-0.0115	-43020991.5468
3.15	0.9017	669.5978	670.4981	0.0003	-0.0109	-0.0116	-43028102.1072
	0.9045	669.4887	670.3823	0.0003	-0.0108	-0.0115	-43021087.2349
	0.9072	669.3803	670.2674	0.0003	-0.0108	-0.0114	-43014119.7597
	0.9098	669.2726	670.1533	0.0003	-0.0107	-0.0113	-43007199.0668
3.20	0.9071	669.3817	670.2690	0.0003	-0.0108	-0.0114	-43014213.5322
	0.9098	669.2740	670.1549	0.0003	-0.0107	-0.0113	-43007292.2803
	0.9125	669.1671	670.0416	0.0003	-0.0106	-0.0113	-43000417.2051
	0.9151	669.0608	669.9291	0.0003	-0.0106	-0.0112	-42993587.7155
3.25	0.9124	669.1685	670.0432	0.0003	-0.0106	-0.0113	-43000508.5759
	0.9151	669.0622	669.9307	0.0003	-0.0106	-0.0112	-42993678.5481
	0.9177	668.9566	669.8189	0.0003	-0.0105	-0.0111	-42986893.5231
	0.9203	668.8518	669.7080	0.0003	-0.0104	-0.0110	-42980152.9314
3.30	0.9177	668.9580	669.8205	0.0003	-0.0105	-0.0111	-42986982.5822
	0.9203	668.8531	669.7095	0.0003	-0.0104	-0.0110	-42980241.4724
	0.9229	668.7489	669.5993	0.0003	-0.0104	-0.0109	-42973544.2348
	0.9255	668.6454	669.4899	0.0003	-0.0103	-0.0109	-42966890.3212
3.35	0.9229	668.7503	669.6009	0.0003	-0.0104	-0.0109	-42973631.0681
	0.9255	668.6467	669.4914	0.0003	-0.0103	-0.0109	-42966976.6553
	0.9280	668.5439	669.3827	0.0003	-0.0102	-0.0108	-42960365.0260

Tabel A-11. Hasil data iterasi reaktor (lanjutan)

Δz	0.0500						
z (m)	**x**	**T (K)**	**Ts (K)**	**dx/dz**	**dT/dz**	**dTs/dz**	**dP/dz**
	0.9306	668.4417	669.2747	0.0003	-0.0102	-0.0107	-42953795.6521
3.40	0.9280	668.5452	669.3842	0.0003	-0.0102	-0.0108	-42960449.7150
	0.9305	668.4430	669.2762	0.0003	-0.0102	-0.0107	-42953879.8598
	0.9331	668.3414	669.1689	0.0003	-0.0101	-0.0107	-42947351.7390
	0.9356	668.2405	669.0624	0.0002	-0.0100	-0.0106	-42940864.8433
3.45	0.9330	668.3427	669.1703	0.0003	-0.0101	-0.0107	-42947434.3613
	0.9355	668.2417	669.0638	0.0002	-0.0100	-0.0106	-42940947.0015
	0.9380	668.1414	668.9579	0.0002	-0.0100	-0.0105	-42934500.3647
	0.9405	668.0418	668.8528	0.0002	-0.0099	-0.0104	-42928093.9597
3.50	0.9380	668.1427	668.9593	0.0002	-0.0100	-0.0105	-42934580.9942
	0.9405	668.0430	668.8542	0.0002	-0.0099	-0.0104	-42928174.1415
	0.9430	667.9439	668.7497	0.0002	-0.0098	-0.0104	-42921807.0361
	0.9454	667.8455	668.6459	0.0002	-0.0098	-0.0103	-42915479.2045
3.55	0.9429	667.9452	668.7511	0.0002	-0.0098	-0.0104	-42921885.7433
	0.9454	667.8467	668.6473	0.0002	-0.0098	-0.0103	-42915557.4796
	0.9478	667.7489	668.5442	0.0002	-0.0097	-0.0102	-42909268.0218
	0.9503	667.6516	668.4417	0.0002	-0.0097	-0.0102	-42903016.9130
3.60	0.9478	667.7500	668.5455	0.0002	-0.0097	-0.0102	-42909344.8739
	0.9502	667.6528	668.4430	0.0002	-0.0097	-0.0102	-42903093.3479
	0.9526	667.5561	668.3412	0.0002	-0.0096	-0.0101	-42896879.7193
	0.9550	667.4600	668.2400	0.0002	-0.0096	-0.0101	-42890703.5468
3.65	0.9526	667.5573	668.3425	0.0002	-0.0096	-0.0101	-42896954.7803
	0.9550	667.4612	668.2413	0.0002	-0.0096	-0.0101	-42890778.2048
	0.9574	667.3656	668.1408	0.0002	-0.0095	-0.0100	-42884638.6493
	0.9597	667.2707	668.0409	0.0002	-0.0094	-0.0099	-42878535.6876
3.70	0.9573	667.3668	668.1421	0.0002	-0.0095	-0.0100	-42884711.9805
	0.9597	667.2718	668.0422	0.0002	-0.0094	-0.0099	-42878608.6293
	0.9621	667.1774	667.9429	0.0002	-0.0094	-0.0099	-42872541.4506
	0.9644	667.0836	667.8442	0.0002	-0.0093	-0.0098	-42866510.0323
3.75	0.9620	667.1785	667.9441	0.0002	-0.0094	-0.0099	-42872613.1104
	0.9644	667.0847	667.8454	0.0002	-0.0093	-0.0098	-42866581.3156
	0.9667	666.9914	667.7474	0.0002	-0.0093	-0.0097	-42860584.8741
	0.9690	666.8986	667.6499	0.0002	-0.0092	-0.0097	-42854623.3877
3.80	0.9667	666.9925	667.7486	0.0002	-0.0093	-0.0097	-42860654.9185
	0.9690	666.8997	667.6511	0.0002	-0.0092	-0.0097	-42854693.0680

Tabel A-11. Hasil data iterasi reaktor (lanjutan)

Δz	0.0500						
z (m)	**x**	**T (K)**	**Ts (K)**	**dx/dz**	**dT/dz**	**dTs/dz**	**dP/dz**
	0.9713	666.8075	667.5542	0.0002	-0.0092	-0.0096	-42848765.7788
	0.9736	666.7158	667.4579	0.0002	-0.0091	-0.0096	-42842872.6658
3.85	0.9712	666.8086	667.5554	0.0002	-0.0092	-0.0096	-42848834.2610
	0.9735	666.7169	667.4591	0.0002	-0.0091	-0.0096	-42842940.7959
	0.9758	666.6257	667.3634	0.0002	-0.0091	-0.0095	-42837081.1261
	0.9781	666.5350	667.2682	0.0002	-0.0090	-0.0095	-42831254.8792
3.90	0.9758	666.6267	667.3645	0.0002	-0.0091	-0.0095	-42837148.0974
	0.9780	666.5361	667.2694	0.0002	-0.0090	-0.0095	-42831321.5097
	0.9803	666.4459	667.1748	0.0002	-0.0090	-0.0094	-42825527.9763
	0.9825	666.3563	667.0808	0.0002	-0.0089	-0.0093	-42819767.1368
3.95	0.9802	666.4469	667.1759	0.0002	-0.0090	-0.0094	-42825593.4855
	0.9825	666.3573	667.0819	0.0002	-0.0089	-0.0093	-42819832.3161
	0.9847	666.2682	666.9884	0.0002	-0.0089	-0.0093	-42814103.4838
	0.9869	666.1795	666.8955	0.0002	-0.0088	-0.0092	-42808406.6398

Resume :

konversi (X)	=	0.98				
suhu gas masuk (Tin)	=	723.15	K	=	450	C
suhu gas keluar (Tout)	=	666.44	K	=	384.29	C
Z (panjang pipa tube)	=	3.95	m	=	155.5118	in
tekanan masuk (P in)	=	2	atm			
tekanan keluar (P out)	=	2	atm			
diameter shell (IDS)	=	1.04	M	=	36.8739	in
suhu pemanas keluar						
(Ts in)	=	473	K	=	200	C

suhu pemanas masuk

(Ts out)	=	667.17	K	=	394	C

j. Mechanical Design

1. Tube

IPS	=	1.25	In
OD	=	1.66	in
Sc. Number	=	40	
ID	=	1.380	in
Flow area per pipe	=	0.435	in^2
Surface per lin ft :			
Outside	=	0.435	ft^2/ft
Inside	=	0.362	ft^2/ft
Weight per lin ft	=	2.2800	lb steel
Panjang pipa	=	202.7559	In
Susunan pipa	=	Triangular pitch	
Jumlah pipa	=	220	Buah
Pitch (jarak antara 2 pusat pipa)	=	2.075	In
Clearance (jarak antara 2 pipa)	=	3.6105	In

Cek SC yang dipilih

Untuk sc number 40

ID = 1.38 in

ODt = 1.66 in

$$TebalTube = \frac{P \times r}{f \times E - 0{,}6P} + C$$

Ketebalan = 0.14 in

Tebal tube = 0.12595 in

Dari table 13.1, halaman 251 Brownell, 1959 diperoleh

Tekanan yang diijinkan (f) = 12650 psi

Efficiency pengelasan (E) = 0.8 (double welded butt joint, table 13.2 Brownell)

Faktor korosi (c) = 0.125 in

2. Shell

a. Tekanan design (maksimal over design 20%)

Tekanan operasi = 2 atm

= 29.4 psi

Tekanan design = 29.4 psi

b. Bahan konstruksi shell

Dipilih material Carbon steel SA 283 C (Brownell, table 13.1 halaman 253)

Peritmbangan karena reactor tidak korosif, dengan suhu operasi 450°C

c. Tebal dinding shell

Tebal dinding shell dihitung dengan persamaan :

$$ts = \frac{Pxr}{fxE - 0.6P} + c$$

Brownell Eq 13.1 page 254

Dimana :

Ts = tebal dinding shell (in)

P = tekanan design (psi)

r=(IDs/2) = radius dalam shell (in)

E = effisiensi sambungan

f = *allowable working stress* (psi)

c = factor korosi (in)

Dari table 13.1 halaman 251 Brownell diperoleh

Tekanan yang diijinkan (f) = 12650 psi

Efficiency pengelasan (E) = 0.8 (double welded butt joint, table 13.2 Brownell)

Faktor korosi (c) = 0.125 in

Dengan IDs = 36.8713 in

Tebal shell (ts) = 0.1625 in

Dipilih tebal dinging standar = 0.1875 in

ODs = IDs + 2 (tebal shell)

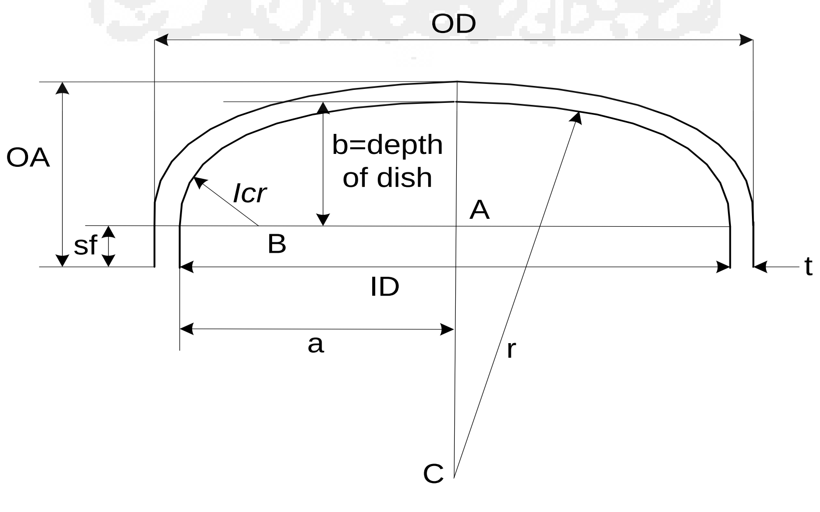
= 37.2463 in

Dari table 5.7 Brownell, dipilih OD standar = 48 in

3. Head Reaktor

a. Bentuk head : elliptical, digunakan untuk tekann operasi hingga 15 bar dan harganya cukup ekonimis,Coulson halaman 818

Digunakan untuk vessel dengan tekanan 15-200 psig, Brownell and Young



b. Bahan Konstruksi Head

Dipilih material Carbon Steel SA 283 C, pertimbangannya adalah reaktor berisi gas beracun, dan suhu operasi antara -20 sampai dengan 650 F

c. Tebal Head (tH)

Untuk *elipstical dished head*, tebal head dihitung dengan persamaan 13.1 (Brownell and Young, 1959)

$$tH = \frac{P.IDs}{2.f.E - 0,2P} + c$$

Dimana :

P = Tekanan Perancangan, Psi

f = Tekanan maksimum yang diijinkan pada bahan, psi

C = *Joint efficiency*, in

E = *Corrosion Allowance*, in

Dipilih material carbon steel SA grade C dari table table 13.1, halaman 251 Brownell

Tekanan yang diijinkan (f) = 12650 psi

Efficiency pengelasan (E) = 0.8 (double welded butt joint, table 13.2 Brownell)

Faktor korosi (c) = 0.125 in

Tebal head reaktor = 0.1282 in

Dipilih tebal head standar = 0.1875 in

d. Tinggi Head

Dari tabel 5.6 brownell hal 88 dengan tH 0.25 in didapat sf $1^1/_2$ - $2^1/_2$ in

Perancangan digunakan sf = 2 in

hH = th + b + sf

= 8.3709 in

Tinggi Reaktor

HF = Panjang tube + top tinggi head

= 4.37 m

Volume Reaktor (VR)

a. Volume head (VH) = 0.000049 x IDs^3 … (Eq 5.11, halaman 88 Brownell 1959)

= 4.024E-05 m^3

b. Volume total reaktor (VR)

Volume total reaktor = Volume bed + 2xVolume head

Volume total reaktor = 2.719 m3

4. Diameter

Umpan masuk G = 4477.010 kg/jam

ρ_{avg} = 2.295 kg/m^3

Diameter Optimum = $3.9\ G^{0.45}\ \rho^{0.13}$ (Coulson, 161)

= 11.433 in

Umpan masuk G = 4477.010 kg/jam

ρ_{avg} = 2.489 kg/m^3

Diameter Optimum = $3.9\ G^{0.45}\ \rho^{0.13}$ (Coulson, 161)

= 11.139 in

Karena selisih diameter tidak jau berbeda maka digunakan diameter terbesar yaitu 11.4333 in

Diameter Standar yang dipakai

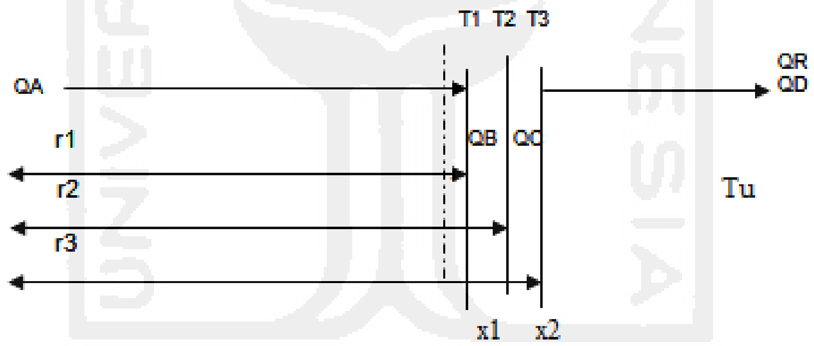
OD = 12.75

ID = 11.938

Isolator

Asumsi ;

1. Keadaan steady state
2. Suhu udara luar 30 °C
3. Suhu dingin luar isolator 50° C



Gambar A-1. Penampang isolator

r_1 = jari jari dalam shell

r_2 = jari jari luar shell

r_3 = jari jari luar setelah diisolasi

x1 = tebal dinding shell

x2 = tebal isolator

T1 = suhu dinding dalam shell = 179.9669 °C = 452.9669 K

T2 = suhu dinding luar shell

T3 = suhu dinding isolator shell = 50 ^{o}C = 323 K

T4 = suhu udara luar = 30 ^{o}C = 303 K

q1 =konveksi bahan ke dinding shell

q2= konduksi dalam shell keluar shell

q3= konduksi luar shell ke permukaan luar isolator

q4 = konveksi dan radiasi permukaan luar isolator ke udara

Keadaan steady state $Q_A = Q_B = Q_C = (Q_D+Q_R)$

r3 = r2 + x

r1	18.4357	in	0.4683	m
r2	18.6231	in	0.4730	m
L =	3.9	m	3.95	m
			12.956	ft

Konduksi

QB = (2.π.ks.L) . (T1 - T2) = 63736.3755 x (T1-T2) (1)

QC = (2.π.kis.L) . (T2 - T3) = 2.3814 x (T2 -T3) / ln (0,6858+x/0,6858) (2)

Konveksi

Bilangan Gr pada L =

Gr = 6.662×10^{10}

Gr Pr = 4.694×10^{10} turbulen

$$h = 1.31 * (\Delta T)^{1/3}$$

hc = 3.230 W/m C

QD = hc . A . (T3-T4)

$QD = hc.2.\pi.r3.L.(T3\text{-}T4) = 1202.125 \text{ x } (0.685+x)$ (3)

Radiasi

$Q_R = \varepsilon\sigma A(T3^4 - Tu^4)$

$Q_R = \varepsilon.\sigma.2.\pi.r_3.L.(T3^4 - Tu^4) = 2485.5881 \text{ x } (0.6858+x)$ (4)

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

T2 = 383.7413 K

x = 0.06 m

sehingga :

Q_D = 640.7676

Q_R = 1324.8905

Q_C = 1724.6373

Q = QD + QR = 1965.6581

Jadi tebal isolasi x = 6 cm

T2 = 383.7413 K

Bahan asbestos, dengan sifat-sifat (Holman, 1988)

ρ = 36 lb/ft3 = 577.0176678 kg/m3

k = 0.117 btu/jam ft2 F

cp = 0.25 btu/lb F

epsilon= 0.96

Data yang diperlukan

Diameter shell, D	=	0.9365	m =	3.0718	ft
tebal plat dinding shell, x1	=	1.25	In =	0.104166667	ft
suhu dinding shell, T1	=	393.4469	C =	666.4469	K
suhu isolator dalam, T3	=	50	C =	323	K
suhu isolator luar, T4	=	35	C =	308	K
Bahan dinding shell	=	Carbon Steel	K =	23.0655	btu/j/ft2/F

hr	40.0197	btu/j/R/ft2
q2	726.3231	π.L.(T1-T2)
q3	0.117	π.L
q4	1095.8934	π.L

LAMPIRAN B

MENARA DISTILASI (MD-01)

Kode : MD-01

Fungsi : Memurnikan produk *Acrylonitrile*

Tujuan : 1. Menentukan tipe kolom distilasi

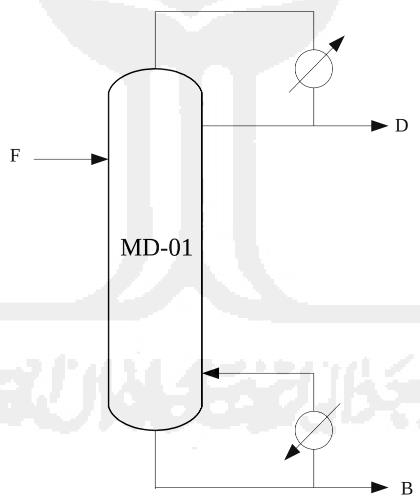
2. Menentukan bahan kontruksi untuk kolom distilasi

3. Menghitung jumlah plate aktual

4. Menentukan lokasi umpan masuk

5. Menentukan dimensi kolom distilasi

Gambar :



1. Menentukan Tipe Kolom Distilasi

Dalam perancangan ini dipilih jenis tray dengan pertimbangan :

1. Rentang batas laju alir yang cukup besar tanpa menimbulkan flooding

2. Umpan yang masuk ke dalam kolom tidak korosif

Jenis *Tray* yang digunakan adalah *Sieve Tray* dengan pertimbangan :

1. Kapasitas uap dan cairannya besar
2. *Pressure drop* rendah dan effisiensi tinggi
3. Lebih ringan, murah dan pembuatannya lebih mudah
4. Biaya perawatan mudah karena mudah dibersihkan dan konstruksinya sederhana

2. Menentukan Bahan Konstruksi Kolom Distilasi

Dipilih bahan konstruksi jenis *Carbon Steel SA-285 grade C* dengan pertimbangan

1. Mempunyai *Allowable Stress* besar
2. Struktur kuat
3. Harga yang relatif lebih murah

3. Menentukan Jumlah Plate dan Feed Plate

Dari hasil perhitungan neraca massa dan neraca panas diperoleh data :

F = 126.57 kmol/jam

D = 60.89 kmol/jam

B = 65.68 kmol/jam

R_{min} = 0.05

R_{aktual} = 0.15

Suhu feed = 391.7 K

Suhu distilat = 389.79 K

Suhu bottom = 407.61 K

Tabel B-1. Jumlah Plate Minimum

Komponen	XF	XD	XB
CH_2CHCN	0.48	0.97	0.01
H_2O	0.51	0.02	0.96
CH_2OHCH_2CN	0.01	0.001	0.01

Jumlah plate minimal dapat dihitung dengan Persamaan *Fenske* :

$$N_m = \frac{\log\left[\left(\frac{x_{LK}}{x_{HK}}\right)_d \left(\frac{x_{HK}}{x_{LK}}\right)_b\right]}{\log \alpha Avg}$$

$$N_m = \frac{\log\left[\left(\frac{0,978}{0,001}\right)_d \left(\frac{0,019}{0,018}\right)_b\right]}{\log 96,027}$$

= 1,7052

Penentuan jumlah plate

Persamaan Underwood :

$$\Sigma \frac{\alpha i . xi, f}{\alpha i - \theta} = Rm + 1$$

Umpan dianggap cair jenuh q = 1

$$\Sigma \frac{\alpha i . xi, f}{\alpha i - \theta} = 1 - q$$

$$\Sigma \frac{\alpha i . xi, f}{\alpha i - \theta} = 0$$

Dengan trial didapat

$$\Sigma \frac{\alpha i . xi, f}{\alpha i - \theta} = -0{,}0007$$

$$\theta = 1{,}0098$$

Rm + 1 = 1,050

Rm = 0,050

R diambil 3Rm

Maka, R = 0,152

Rm/(Rm+1) = 0,048

R/(R+1) = 0,132

Dari fig. 11.11 Coulson diperoleh,

Nm/N = 0,3

N = 5,68 ≈ 6 plate

Jumlah plate teoritis = 6 plate

Menentukan jumlah plate actual

Tabel B-2. Viskositas Campuran

Komponen	**XF**	**μ (cp)**	**XF.μ (cp)**
C_3H_3N	0.48	1.56E-01	7.50E-02
H_2O	0.51	2.17E-01	1.11E-01
C_3H_5ON	0.01	2.34E-01	2.29E-03
Total			**6.27E-02**

$\mu_{Faverage}$ = 6.27E-02 cp

$\alpha_{average}$ = 96,02

$(\alpha_{average})\ (\mu_{Faverage})$ = 6.27E-02 x 96,02

Efficiency plate, Eo

$Eo = 51 - 32{,}5 \text{ Log } (\alpha_{average})\ (\mu_{Faverage})$ *(Coulson & Richardson, P.442)*

Dimana :

αa = Volatilitas rata-rata komponen light key.

μa = Viskositas rata-rata molar cairan, mNs/m^2

Eo = 51-32,5 Log (96,02 x 6.27E-02)

Eo = 25,65 %

Nactual = N / Eo

= 23,39 stage

= 23 stage

4. Menentukan Lokasi Umpan Masuk

Persamaan yang dapat digunakan adalah :

$$\log\left(\frac{n}{m}\right) = 0{,}206\log\left[\left(\frac{B}{D}\right)\left(\frac{X_{hK}}{X_{LK}}\right)_F\left(\frac{X_{LKB}}{X_{hKD}}\right)^2\right]$$

(Coulson and Richardson, 1983 : 422)

Dengan :

n = Plate ideal di atas lokasi umpan

m = Plate ideal di bawah lokasi umpan

B = Laju alir produk bawah

D = Laju alir produk atas

Sehingga : $Log\left(\frac{n}{m}\right) = 0{,}206 Log\left[\left(\frac{1290{,}71}{3186{,}29}\right)\left(\frac{0{,}01}{0{,}48}\right)\left(\frac{0{,}01}{0{,}001}\right)^2\right]$

$\left(\frac{n}{m}\right)$ = 1,79

n + m = Nact

n + m = 23

m = 15,01

Jadi umpan masuk di plate ke 15 dari dasar menara distilasi

5. Menghitung Dimensi Kolom Distilasi

Densitas

Diketahui kondisi operasi distilat:

T = 391,7 K

P = 3 atm

Tabel B-3. Densitas uap (ρ_L) dan BM campuran Distilat

Komponen	F (kmol/jam)	BM	Xi (% kmol)	pL (g/mL)	pL mix (g/mL)	Xi. ρ (kg/m3)
C_3H_3N	59.57	53,06	0.97	0.96	0.94	943,39
H_2O	1.29	18,02	0.02	0.93	0.01	19,85
C_3H_5ON	0.02	71,08	0.00	0.68	0.0002	2,79
Total	**60.8948**		**1.0000**	**1,0000**	**0.9641**	**964,11**

Densitas cairan (ρ_L) = 964,11 kg/m^3

BM campuran = 52.3246 kg/Kmol

R = 0,082057 m^3 atm/gmol K

$$\rho_V = \frac{BM \times P}{R \times T} = \frac{52.3246 \times 3}{0,082057 \times 391,7} = 4,8844 kg / m^3$$

Diketahui kondisi operasi bottom:

P = 3 atm

T = 407,6 K

Tabel B-4. Densitas uap (ρ_L) dan BM campuran Bottom

Komponen	F (kmol/jam)	BM	Xi (% kmol)	pL (g/mL)	pL mix (g/mL)	Xi. ρ (kg/m3)
C_3H_3N	1.21	53,06	0.018	0.950	0.017	17,601
H_2O	63.25	18,02	0.963	0.919	0.885	885,770
C_3H_5ON	1.21	71,08	0.018	0.661	0.012	12,249
Total	**65.6824**		**19,429**		**0.91562153**	**915.621**

Densitas cairan (ρ_L) = 915.62 kg/m^3

BM campuran = 19.65 kg/kmol

R = 0,08 m^3 atm/gmol K

$$\rho_V = \frac{BM \times P}{R \times T} = \frac{19,65 \times 3}{0,082 \times 407,6} = 1,76 kg / m^3$$

Coloumn Diameter

top product (D)	=	3186.29	kg/jam
vapor rate (V)	=	3673.005	kg/jam
liquid rate (L)	=	486.71	kg/jam
bottom product (B)	=	1290.71	kg/jam

B = L'-V' = 1290.71 kg/jam

L' = F*q+R*D = L + F = 4963.72 kg/jam

liquid rate (V' = L'-B) = 3673.005 kg/jam

L'/V' = 1.35

$$F_{LV} = \frac{L}{V}\left(\frac{\rho_V}{\rho_L}\right)^{0,5}$$

F_{LV} distilat = 0,0094

F_{LV} bottom = 0,0593

Kisaran Plate Spacing untuk diameter > 1m biasanya digunakan Plate Spacing 0,3-0,6 m, diambil 0,3 m

Dari fig 11.27 Coulson and Rhichardson, diperoleh nilai C_f distilat = 0,11 ; C_f bottom = 0,1 dengan parameter F_{LV} dan plate spacing

Kecepatan Flooding dengan persamaaan Fair

$$V_F = C_F\left(\frac{\rho_L - \rho_V}{\rho_V}\right)^{0,5}$$

V_f distilat = 1,54 m/det

V_f bottom = 2,27 m/det

Dalam perancangan ini, prosentasi *Flooding* sebesar 90% maka :

V_F distilat = 1,38 m/det

V_F bottom = 2,04 m/det

Distilat

$$An = \frac{Q_V}{V_F}$$

$$Q_V = \frac{V_V}{\rho_L} = \frac{3673{,}005 kg/\det ik}{964{,}11 kg/m^3} = 0{,}208 \text{ m}^3\text{/detik}$$

$$An = \frac{0{,}208 m^3 / \det ik}{1{,}387 m/\det ik} = 0{,}15 \text{ m}^2$$

Bottom

$$An = \frac{Q_V}{V_F}$$

$$Q_V = \frac{V_V}{\rho_L} = \frac{3673{,}005 kg/\det ik}{915{,}62 kg/m^3} = 0{,}578 \text{ m}^3\text{/detik}$$

$$An = \frac{0{,}578 m^3 / \det ik}{2{,}049 m/\det ik} = 0{,}282 \text{ m}^2$$

Down Comer Area

diambil 20% dari total Colomn Area

Distilat

$$At = \frac{A_n}{1 - Downspot} = \frac{0{,}150}{1 - 0{,}2} = 0{,}188 m^3$$

Bottom

$$At = \frac{A_n}{1 - Downspot} = \frac{0{,}282}{1 - 0{,}2} = 0{,}353 m^3$$

Diameter puncak menara dihitung dengan persamaan :

$$D = \left(\frac{4.At}{\pi} \right)^{0,5} = \left(\frac{4 \times 0,188}{3,14} \right)^{0,5}$$

= 0,4896 m

Diameter dasar menara dihitung dengan persamaan :

$$D = \left(\frac{4.At}{\pi} \right)^{0,5} = \left(\frac{4 \times 0,353}{3,14} \right)^{0,5}$$

= 0,67 m

Karena selisih diameter kecil maka digunakan diameter terbesar yaitu 0,67 m untuk puncak maupun dasar menara.

Menghitung tebal Shell kolom

Bahan konstruksi *Shell* yang dipilih adalah *Carbon Steel SA-285 grade C* dengan spesifikasi :

- *Allowable Stress (f)* = 38,2054 psia (*Table 13-1, hal 251 Brownell*)
- Effisiensi pengelasan (E) = 0,8
- Faktor korosi (c) = 0,125

Tebal shell (ts) dapat dihitung dengan persamaan :

$$ts = \frac{P.r}{f.E - 0,6.P} + C$$ (*Pers. 13-1, hal 254 Brownell*)

Sehingga :

$$ts = \frac{38,2054 \times 0,67/2}{(12635,3 \times 0,8) - (0,6 \times 38,2054)} + 0,125 = 0,175 in$$

Digunakan tebal standar = 0,1875 in = 4,7625 mm (*Table 5-6, hal 88 Brownell*)

Menghitung tebal head

Tebal head dihitung dengan persamaan :

$$th = \frac{0,885.\,Pr}{(f.E)-(0,1.P)} + C \qquad (\textit{hal 254, Brownell})$$

OD = ID + 2 ts

= (26,40) + (2 x 0,1875)

= 26,7786 in

Digunakan OD standar = 32 in

Dari *Table 5-7*, *Brownell* dengan OD = 32 in dan tebal *Shell* 0,1875 in

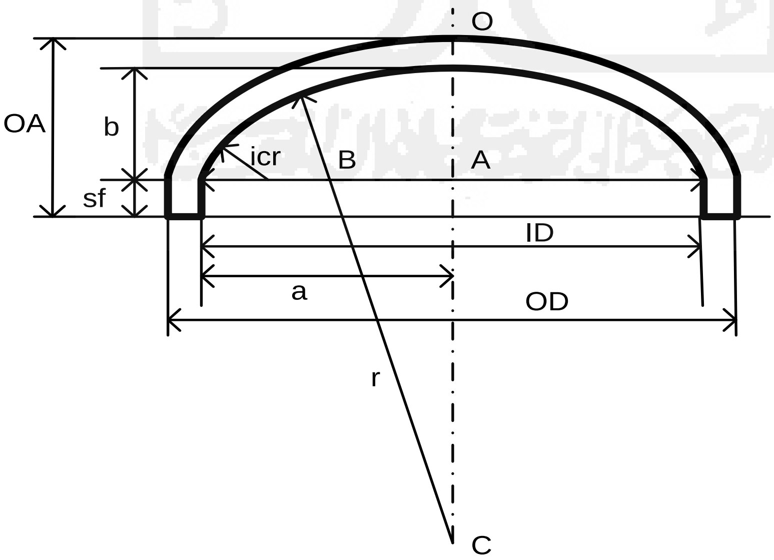
Sehingga tebal *Head*

$$th = \frac{0,885.38,2054.32}{(12635,3 \times 0,8)-(0,1 \times 38,2054)} + 0,125 = 0,2321 in$$

Digunakan tebal *Head* standar = 1/4 in = 0,25 in

Menghitung tinggi total kolom distilasi

Tinggi total kolom = Tinggi kolom + Tinggi *Head* puncak + Tinggi *Head* dasar



Gambar B-1. Dimensi Head

Dari *Table 5-6, Brownell* diperoleh :

Th = 1/4 in

Sf = 1½ - 2½ in diambil 2½ in

Icr = 2 in

rc = 30 in

$$a = \frac{ID}{2} = \frac{31,625}{2}$$

= 15,8125 inchi

$$AB = a - i_{cr}$$

= 13,812 inchi

$$BC = r_c - i_{cr}$$

$$= 30 - 2$$

= 28 inchi

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

$$= \sqrt{(28^2) - (13,812^2)}$$

= 24,3560 inchi

$$b = r_c - AC$$

$$= 30 - 24,3560$$

= 5,6440 inchi

$$OA = t + b + s_f$$

$$= 0,25 + 5,6440 + 2$$

= 7,8940 inchi

= 0,2005 m

Jadi tinggi *head* = 0,2005 m

Jadi tinggi kolom distilasi total = 8,717 m + 0,2005 m + 0,2005 m

= 9,118 m

DAFTAR PUSTAKA

Aries, R.S., and Newton, R.D., 1955, Chemical Engineering Cost Estimation, Mc Graw Hill Handbook Co., Inc., New York.

Biro Pusat Statistik, 2009-2014, Statistik Perdagangan Luar Negeri Indonesia, Indonesia foreign, Trade Statistic Import, Yogyakarta.

Brown, G.G., Donal Katz, Foust, A.S., and Schneidewind, R., 1978, Unit Operation, Modern Asia Edition, John Wiley and Sons, Inc., New York.

Brownell, L.E., and Young, E.H., 1959, Process Equipment Design, John Wiley and Sons, Inc., New York.

Coulson, J.M., and Richardson, J.F., 1983, Chemical Engineering, Vol 1 $ 6, Pergamon Internasional Library, New York.

Evans, F.L., 1980, Equipment Design Handbook for Refineries and Chemical Plant, Vol. 2, 2nd ed, Gulf Publishing Co., United Stated of America.

Faith Keyes and Clark, 1975, " Industrial Chemical", 4th Edition, Jonh Wiley and Sons Inc., New York.

Holman, J., 1981, Heat Transfer, Mc Graw Hill Book Co., Inc., New York.

Kern, D.Q., 1983, Process Heat Transfer, Mc Graw Hill Book Co., Inc., New York.

Kirk, Othmer., 1998, Encyclodpedia of Chemical Technology, 3rd ed, Vol. 1. John Wiley and Sons, Inc., New York.

Levenspiel, O., 1972, Chemical Reaction Engineering, 2nd ed., John Wiely and Sons, Inc., New York.

Ludwig, E.E., 1964, Applied Process Design for Chemical and Petrochemical Plants, Gulf Publishing, Co., Houston

Mc Cabe, Smith, J.C., and Harriot, 1985, Unit Operation of Chemical Engineering, 4th ed., Mc Graw Hill Book Co., Inc., New York

Perry, R.H., and Green, D.W., 1986, Perry's Chemical Engineer's Handbook, 6th ed., Mc Graw Hill Book Co., Inc., New York

Peters, M.S., and Timmerhaus, K.D., 1980, Plant Design and Economics for Chemical Engineers, 3rd ed., Mc Graw Hill Book Co., Inc., New York

Powell, P.T., 1954, Water Conditioning for Industry, Mc Graw Hill, Inc., New York

Treyball, R.E., 1981, " Mass Transfer Operation ", 3nd Edition, Mc. Graw Hill Book Company Inc., Singapore.

Ulrich, G.G., 1984, A Guide to Chemical Engineering Process Design and Econimics, John Wiley and Sons, New York.

Walas, S.M., 1988, Chemical Process Equipment Selection and Design, 3rd ed, Butterworth, United States of America.

Yaws, C.L., 1999, Chemical Properties Handbook, Mc Graw Hill Company, Inc., New York.

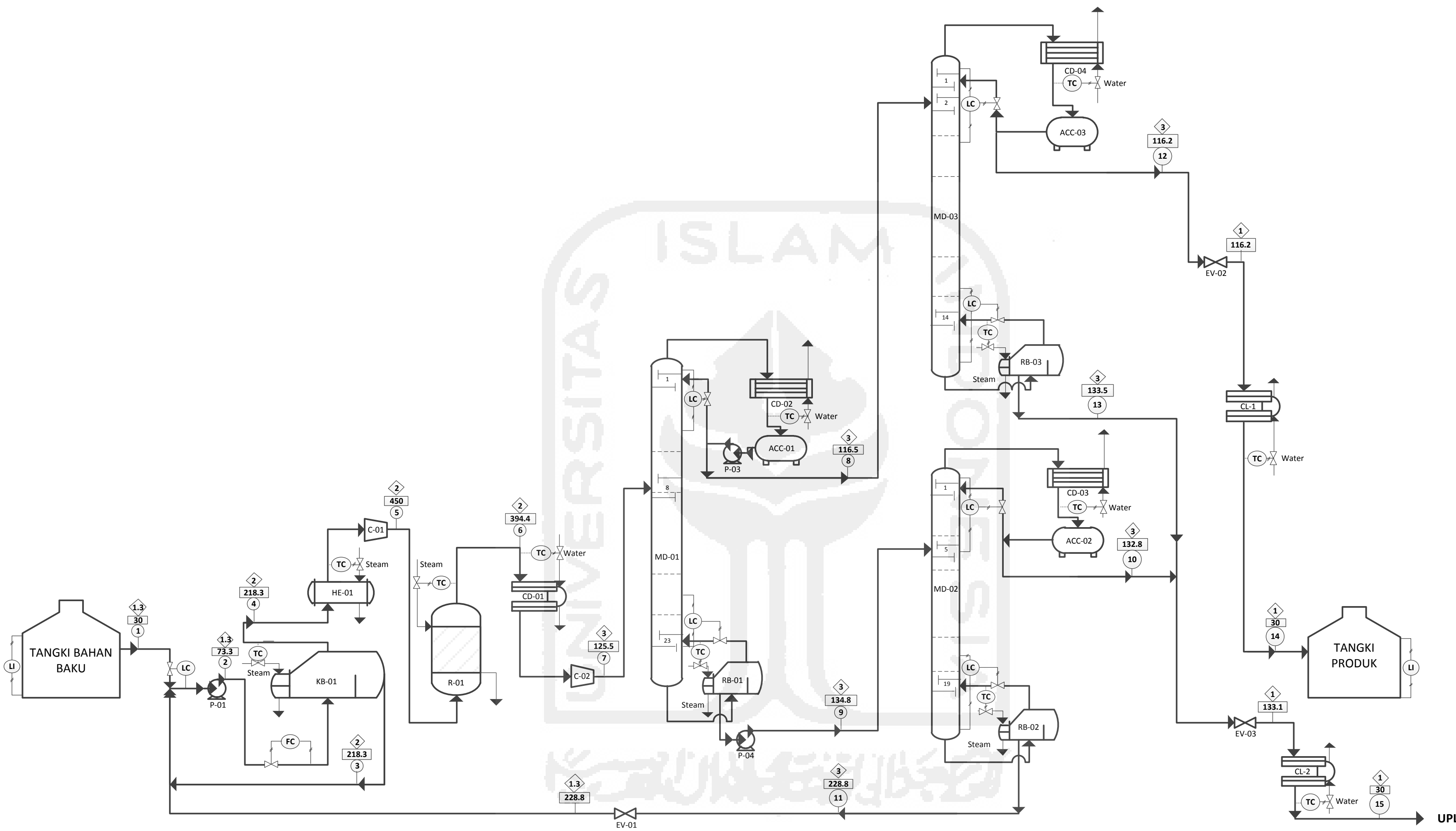
http://www.alibaba.com untuk harga alumina

http://www.matche.com untuk harga alat

http://www.pajak.go.id

Tecnon Orbichem. 2010. orbichem.com

PROCESS ENGINEERING FLOW DIAGRAM
PABRIK AKRILONITRIL DARI ETILEN SIANOHIDRIN
KAPASITAS PRODUKSI 25.000 TON/TAHUN



Komponen	Nomor Arus (kg/jam)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C_3H_5ON	4323,08	5511,71	1102,34	4409,37	88,19	88,19	88,19	1,76	86,42	0,13	86,29	0,00	1,76	0,00	1,89
H_2O	65,83	84,43	16,89	67,54	1163,04	1163,04	1163,04	23,26	1139,78	1138,07	1,71	0,03	23,23	0,03	1161,29
C_3H_3N	0,00	0,12	0,02	0,10	3225,79	3225,79	3225,79	3161,27	64,52	64,42	0,10	3156,53	4,74	3156,53	69,16
Total	4388,91	5596,26	1119,25	4477,01	4477,01	4477,01	4477,01	3186,29	1290,72	1202,62	88,10	2156,57	29,73	3156,57	1232,34

KETERANGAN

R : REAKTOR
MD : MENARA DISTILASI
CD : KONDENSER
KB : KETTLE REBOILER
RB : REBOILER
HE : HEATER
C : COOLER
LC : LEVEL CONTROLLER
TC : TEMPERATURE CONTROLLER
LI : LEVEL INDICATOR
EV : EXPANSION VALVE

CL : COOLER
C : COMPRESSOR
P : POMPA
○ : NOMOR ARUS
◇ : TEKANAN, atm
▭ : TEMPERATUR, °C
— : ARUS UTAMA
-//- : UDARA TEKAN
--- : ARUS LISTRIK
⋈ : KONTROL VALVE

PROGRAM STUDI TEKNIK KIMIA S-1
FAKULTAS TEKNOLOGI INDUSTRI
UNIVERSITAS ISLAM INDONESIA
YOGYAKARTA
2016

PROCESS ENGINEERING FLOW DIAGRAM
PRA-RANCANGAN PABRIK AKRILONITRIL
DARI ETILEN SIANOHIDRIN
KAPASITAS PRODUKSI 25.000 TON/TAHUN

DIKERJAKAN OLEH :
1. RADHITYA BANUAJI PRASTOWO (12521127)
2. ERIKA DWI OKTAVIANI (12521161)

DOSEN PEMBIMBING :
1. SHOLEH MA'MUN, Ph.D