LAMPIRAN

REAKTOR

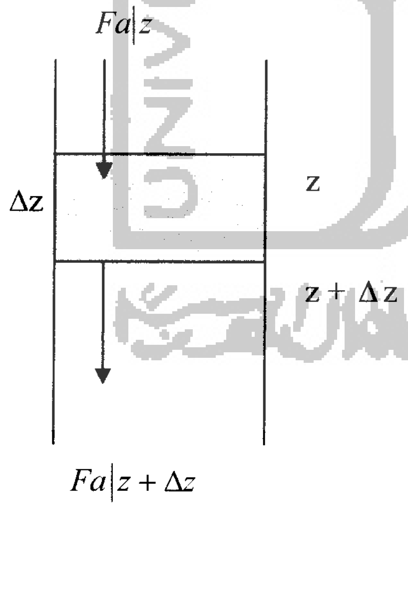
Tugas : Mereaksikan ethylene dengan steam membentuk ethanol

Type : Fixed Bed Multi Tube

PERSAMAAN DIFFERENSIAL

1. Neraca Massa pada Elemen Volume

Ditinjau untuk 1 pipa



Input – Output = Akumulasi

$$Fa\Big|_{z} - \left(Fa\Big|_{z+\Delta z} + (-r\Lambda).\Delta v.\rho B \right) = 0$$

$$Fa\Big|_{z} - Fa\Big|_{z+\Delta z} - (-r\Lambda).\Delta V.\rho B = 0$$

$$Fa\Big|_{z} - Fa\Big|_{z+\Delta z} = (-r\Lambda).\Delta V.\rho B$$

$$\Delta V = \frac{\pi.Di^2}{4}.\rho B.\Delta z$$

$$Fa\Big|_{z} - Fa\Big|_{z+\Delta z} = \frac{(-r\Lambda).\pi.Di^2.\rho B.\Delta z}{4}$$

$$Fa\Big|_{z} - Fa\Big|_{z+\Delta z} = \frac{(-r\Lambda).\pi Di^2.\rho B}{4}$$

$$-\frac{\Delta F\Lambda}{\Delta z} = \frac{(-r\Lambda).\pi.Di^2.\rho B}{4}$$

$$F\Lambda = F\Lambda_0(1 - X\Lambda)$$

$$\Delta F\Lambda = -F\Lambda_0.\Delta X_\Lambda$$

$$FA_O \frac{.\Delta X_A}{\Delta z} = \frac{(-r_A).\pi.Di^2.\rho_B}{4}$$

$$\frac{\Delta X_A}{\Delta Z} = \frac{(-r_A).\pi.Di^2.\rho_B}{4F_{AO}}$$

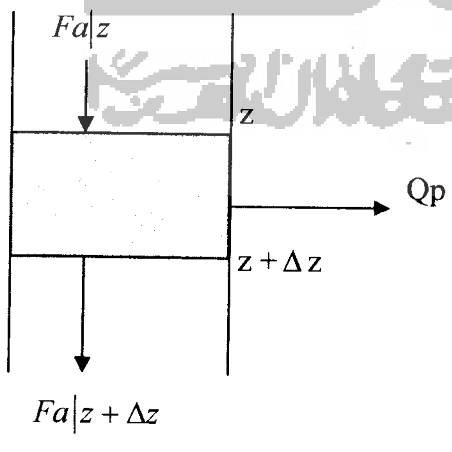
$\lim \Delta Z \rightarrow 0$

$$\boxed{\frac{dX_A}{dZ} = \frac{(-r_A).\pi.Di^2.\rho_B}{4.F_{AO}}}$$

dimana :

dX_A / dz	= perubahan konversi per satuan panjang
$(-r_A)$	= kecepatan reaksi kimia
Di	= diameter dalam pipa
F_{AO}	= kecepatan molar A mula-mula
ρ_B	= densitas bulk, gr/cm^3

2. Neraca Panas pada Elemen Volume



Input – Output = Akumulasi

$$\left(\sum m.cp\right)\left(T|z - T_O\right) - \left[\sum m.cp\left(T\Big|z + \Delta z - T_O\right) + \Delta HR_T.F_{AO}.\Delta X_A + U.A(T - Ts)\right]$$

$$\sum m.cp\left(T|_Z - T_O\right) - \sum m.cp\left(T|_{Z+\Delta Z} - T_O\right) = \Delta HR_T.F_{AO}.\Delta X_A + U.A.(T - Ts)$$

$$A = \pi.D_O.\Delta_Z$$

maka :

$$\sum m.cp\left(T|_Z - T|_{Z+\Delta Z}\right) = \Delta HR_T.F_{AO}.\Delta X_A + U.\pi.D_O.\Delta_Z.(T - Ts)$$

$$\frac{\left(T|_Z - T|_{Z+\Delta Z}\right)}{\Delta_Z} = \frac{\Delta HR_T.F_{AO}.\frac{\Delta X_A}{\Delta Z} + U.\pi.Do.(T - Ts)}{\sum m.cp}$$

$$-\frac{\Delta T}{\Delta z} = \frac{\Delta HR_T.F_{AO}.\frac{\Delta X_A}{\Delta z} + U.\pi.Do.(T - Ts)}{\sum m.cp}$$

lim $\Delta Z \to 0$

$$-\frac{dT}{dZ} = \frac{\Delta HR_T.F_{AO}.\frac{dX_A}{dz} + U.\pi.Do.(T - Ts)}{\sum m.cp}$$

$$\boxed{\frac{dT}{dz} = \frac{-\Delta HR_T.F_{AO}.\frac{dX_A}{dz} + U.\pi.Do.(T - Ts)}{\sum m.cp}}$$

dimana:

dT/dz : perubahan suhu per satuan panjang

$\Delta H R_T$: panas reaksi

U : overall heat transfer

Do : diameter luar pipa

Ts : suhu pendingin

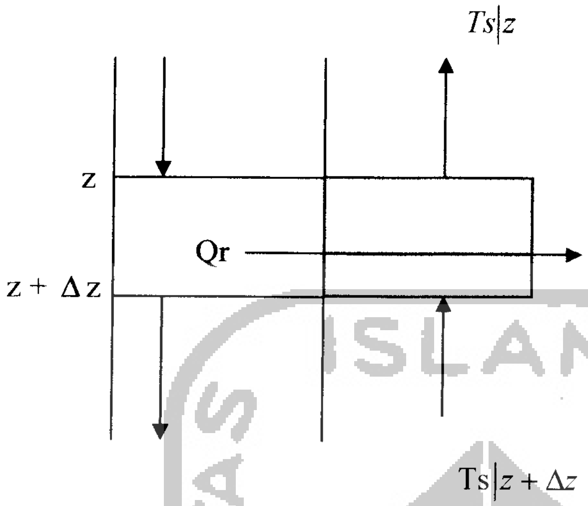
$\sum m.cp$: kapasitas panas campuran

3. Neraca Panas pada Pendingin

Pendingin yang dipakai adalah Dowtherm A. Sifat-sifat fisis Dowterm A:

- Tidak bereaksi kimiawi dengan logam
- Tidak beracun
- Stabil pada suhu 200 – 750 °F
- $Cp = 0{,}11152 + 3{,}402 \ . \ 10^{-4}\ T$, cal/gr.^{0}K
- $\rho = 1{,}3644 - 9{,}7073 \ . \ 10^{-4}\ T$, gr/cm^3
- $\mu = 35{,}5898 - 0{,}04212\ T$, gr/cm.jam
- $k = 0{,}84335 - 5{,}8076 \ . \ 10^{-4}$, cal/jam.cm.^{0}K

Aliran pendingin dalam reaktor berlawanan arah dengan aliran gas.



Input – Output = Akumulasi

$$\left(\sum m.cP\right)p.\left(Ts\big|_{Z+\Delta Z} - To\right) + U.A(T - Ts) - \left(\sum m.cP\right)p.\left(Ts\big|_{Z} - To\right) = 0$$

$$\left(\sum m.cP\right)p.\left(Ts\big|_{Z+\Delta Z} - Ts\big|_{Z}\right) = -U.A(T - Ts)$$

A $= \pi.\ Do.\ \Delta z$

$$\left(\sum m.cP\right)p\left(Ts\big|_{Z+\Delta Z} - Ts\big|_{Z}\right) = -U.\pi.Do.\Delta z(T - Ts)$$

$$\frac{\left(Ts\big|_{Z} - Ts\big|_{Z+\Delta Z}\right)}{\Delta z} = \frac{U.\pi.Do.(T - Ts)}{(m.cP)p}$$

$$\frac{\Delta Ts}{\Delta z} = \frac{-U.\pi.Do.(T - Ts)}{(m.cP)p}$$

lim $\Delta z \rightarrow 0$

$$\frac{d\mathrm{T}s}{dz} = \frac{-U.\pi.Do.(\mathrm{T}-\mathrm{T}s)}{(m.c\mathrm{P})\,p}$$

dimana:

dTs/dz : perubahan suhu pendingin per satuan panjang

(Σm.c P)p : kapasitas panas pendingin

4. Penurunan Tekanan (*Pressure Drop*)

Penurunan tekanan dalam pipa yang berisi katalisator (fixed bed) dipakai rumus 11.6,11.7,11.8, B (Rase, hal. 492)

sehingga :

$$\frac{gc.dp}{Vs.dz} = 150\frac{(1-E)^2}{E^3}.\frac{\mu}{Dp^2} + 1{,}75\frac{(1-E)}{E^3}.\frac{G}{Dp}$$

$$\mathrm{fk} = 1{,}75 + 150\left(\frac{1-E}{Dp.G/\mu}\right)$$

$$\frac{dp}{dz} = -\frac{fk.Gt^2}{Dp.RM.gc}\left(\frac{1-E}{E^3}\right)$$

dimana:

Gt : kecepatan aliran massa gas dalam pipa, gr/cm^2.jam

Dp : diameter partikel katalisator, cm

Gc : gaya gravitasi, cm/jam

E : porositas tumbukan katalisator

μ : viskositas gas, gr/cm.jam

5. Katalisator

Jenis : Asam Phospat dengan Silika Gel

Bentuk : silinder

Ukuran D : 5/32 in = 0,3969 cm

L : 5/32 in = 0,3969 cm

Bulk density : 200 kg/cm^3 = 0,2 gr/cm^3

Bila dinyatakan dalam diameter ekuivalen : yaitu diameter bola yang mempunyai volume yang sama dengan silinder (partikel), maka:

$$Vs = \frac{\pi}{4}.D^2.L$$

$$= \frac{\pi}{4}.(0{,}3969)^2.(0{,}3969)$$

$$= 0{,}0491 \text{ cm}^3$$

$$Vb = \frac{\pi}{6}.(Dp)^3$$

$$0{,}0491 = \frac{\pi}{6}.(Dp)^3$$

$$Dp = \left(\frac{6.0{,}0491}{\pi}\right)^{1/3}$$

$$= 0{,}4543 \text{ cm}$$

6. Pemilihan Pipa

Diameter reaktor dipilih berdasarkan pertimbangan agar perpindahan panas berjalan dengan baik. Karena reaksinya eksotermis maka dipilih aliran gas dalam pipa turbulen agar perpindahan panasnya besar.

Pengaruh rasio Dp/Dt terhadap koefisien perpindahan panas dalam pipa yang berisi butir-butir katalisator dibandingkan dengan pipa kosong yaitu : hw/h, telah diteliti oleh Colburn's (Smith, Chemical Kinetics Engineering, hal 571) yaitu:

Dp/Dt	0,05	0,1	0,15	0,2	0,25	0,3
hw/h	5,5	7,0	7,8	7,5	7,0	6,6

dipilih Dp/Dt = 0,15

dimana:

hw : koefisien perpindahan panas dalam pipa berisi katalis

h : koefisien perpindahan panas dalam pipa kosong

Dp : diameter katalisator

Dt : diameter tube

sehingga:

Dp/Dt = 0,15

Dp = 0,4543 cm

$$Dt = \left(\frac{0,4543}{0,15}\right)$$

$$= 3,0289 \text{ cm}$$

$$= 1,1925 \text{ inch}$$

dari hasil perhitungan tersebut maka diambil ukuran pipa standar agar koefisien perpindahan panasnya baik. (Kern)

Dari tabel 11 Kern, Process Heat Transfer, hal 844 dipilih pipa dengan spesifikasi sebagai berikut:

nominal pipe side	= 1,5 inch
out side diameter	= 4,826 cm
inside diameter	= 4,0894 cm
flow area per pipe	= 2,04 inch
surface per lin.ft	= 0,422 ft^2/ft
surface luar	= 0,498 ft^2/ft
sc number	= 40

7. Mencari UD (Design Overall Coefficient)

hi untuk aliran turbulen dalam pipa dapat dihitung dengan rumus 6-2 Kern, Process Heat Transfer, hal 103 :

$$hi = 0,027.\frac{k}{Di}.(RE)^{0,8}(PR)^{1/3}$$

$$RE = \frac{GT.DP}{\mu_R} \quad ; \quad PR = \frac{Cpm.\mu R}{k}$$

dimana :

k: konduktivitas campuran gas, cal/j.m.k

$$k: \frac{\sum yi.ki(Bmi)^{1/3}}{\sum yi.(Bmi)^{1/3}}$$ (perry, 5-ed.3-249)

keterangan:

BMi : berat molekul gas

yi : fraksi mol

Re : bilangan Reynold

Dp : diameter partikel katalisator, cm

GT : kecepatan massa campuran gas, gr/jam^2

μR : viskositas campuran gas, gr/dt.cm

$$: \frac{\sum yi.\mu i.(BMi)^{1/2}}{\sum yi.(BMi)^{1/2}}$$ (perry,5-ed. 3-249)

PR : prandtl number

Cp : kapasitas panas campuran gas, ml/g.mol.^{0}K

: $\sum$ Cpi.yi

μp : viskositas pendingin, gr/dt.cm

Kp : konduktivitas pendingin, cal/j.m.^{0}K

ID : diameter dalam pipa,cm

Dari perhitungan sebelumnya untuk perbandingan Dp/Dt = 0,15 maka hiw/hi = 7,8. harga ini dari data hasil penelitian Colburn's (Smith, Chemical Engineering Kinetics, hal 511) sehingga:

hi katalisator = 7,8 . hi (tanpa katalisator)

Harga ho dapat dihitung dengan persamaan:

$$ho = 0{,}36.\ \frac{Kp}{De}(REs)^{0,55}(PRs)^{1/3}$$

dimana:

Kp : konduktivitas pendingin Dowtherm A. cal/j.m.^{0}K

De : diameter shell, cm

REs : bilangan Reynolds = DE.GS/VP

PRs : bilangan Prandtl = CPP. μp/Kp

De : $\frac{4.(Ptc^2 - \pi.OD^2)/4}{\pi.OD}$

Asi : $\frac{ID.CL.B}{Ptc}$ CL = Ptc-OD

B = 0,25 x ID

Ptc = 1,25 x OD

Gs : $\frac{ms}{Asi}$

dimana:

Cl : Clearance antar tube, cm

B : Baffle spacing, cm

Asi : Flow area shell, cm^2

ms : Weight flow pendingin

Gs : Kecepatan massa dalam shell. G/j.cm^2

Ptc : pitch

8. UC (Koefisien Overall pada Pipa Bersih)

$$UC = \frac{hio \times ho}{hio + ho}, cal/j.^{0}K.cm^{2}$$

$$\text{dengan hio} = \frac{hi \times ID}{OD}$$

9. Dirty Factor/Fouling Factor (Rd)

Dari Kern, Process Heat Transfer, hal 845 diperoleh

Untuk uap organic, Rd : 0,0005

Untuk cairan organic, Rd : 0,001

Rd total = 0,0005 + 0,001 = 0,0015 $ft^2 j\ ^0F/Btu$

= 0,00307 J $cm^{2\ 0}K/cal$

sehingga:

$$UD = \frac{UC}{Rd(UC+1)}, cal/jcm^{2\,0}K$$

= 1 / (0.00307 + 1)

= 0.9969 cal / jcm^2 K

10. Menghitung Jumlah Pipa

Dari fig 2.22 Brown "Unit Operation" hal 213 berdasarkan perbandingan Dp/Dt didapat porositas (E) = 0,36

$$Faktor\ Sphericity\ (Y) = \frac{luas\ permukaan\ bola\ dengan\ volume\ partikel}{luas\ permukaan\ partikel}$$

$$Y = \frac{\pi . Dp^2}{\left[\pi . D . L + (2 . \frac{\pi}{4} . D^2) \right]}$$

$$= \frac{3{,}14.(0{,}4543^2)}{\left[3{,}14.0{,}3969.0.3969 + 2(3{,}14/4)(0{,}3969^2) \right]}$$

$$= 0{,}7968$$

dari fig 219 Brown hal 211 didapat F_{RE} = 50,8

maka

$$Re = \frac{F_{RE} . GT . DP}{\mu} \quad ; \mu \text{ camp} = 5{,}11947.10^{-4} \text{ gr/dt.cm}$$

luas penampang pipa (Ao) = $\frac{\pi}{4}$.ID^2

= 3,14/4(4,0894)^2 = 13,1277 cm^2

Re = 3100 → aliran turbulen (Re>>>)

GT = (6000 x μ) / Dp

= 6000 x (0.000661 / 4.0894) = 0.9699 gr/dt.cm^2

kecepatan umpan gas (G)

$$G = \frac{26640.6993 \times 1000}{3600} = 7400{,}1942 \text{ gr/dt}$$

At = G/Gt

= 7400,1942/0,7511 = 9852.0427 cm^2

Jumlah pipa maksimum

Nt_{max} = At/A_0 = 9149,3110/13,1277 = 750,4777 ≈ 750 pipa

```
CLS
 PRINT TAB(5); "========================================"
 PRINT TAB(5); " Perhitungan Reaktor Fixed Bed Multitube"
 PRINT TAB(5); "       Oleh : Gatot & Sari"
 PRINT TAB(5); "       NIM = 02521238 & 02521258"
 PRINT TAB(5); "----------------------------------------"

 phi = 3.14159: R = .082057: 'm^3.atm/kgmol/k

 'Spesifikasi reaktor
 REM Bagian Tube
 ID = 1.61 * .0254: OD = 1.9 * .0254:      'm
 Pt = 1.25 * OD: Cl = Pt - OD
 Nt = 300: At = Nt * phi * ID ^ 2 / 4:

 REM Bagian Shell
 IDs = ((4 * .866 * Nt * Pt ^ 2) / phi) ^ .5: Bs = IDs * .25
 ASs = IDs * Cl * Bs / Pt
 Des = 4 * (.5 * .866 * Pt ^ 2 - (.5 * phi * (OD ^ 2) / 4)) / .5 / phi / OD

 'Kondisi Masuk Reaktor
 Tf = 523: Pf = 68: Tpf = 520
 Tp0f = ((Tpf - 273) * 1.8) + 32: 'F

 ' Katalisator
 Dpar = .3969: pore = .4: Rhob = 200

 'Umpan Reaktor,kmol/jam
 F10 = 533.6889: 'etilen
 F20 = 444.7407: 'air
 F30 = 1.2036:  'etana
 F40 = 0:  'etanol
 Ftot0 = F10 + F20 + F30 + F40

 'Berat Molekul,kg/kmol
 BM(1) = 28: BM(2) = 18: BM(3) = 30:
 BM(4) = 46

 'Umpan Reaktor,kg/jam
 W10 = F10 * BM(1): W20 = F20 * BM(2): W30 = F30 * BM(3):
 W40 = F40 * BM(4)
 Wtot0 = W10 + W20 + W30 + W40
 Gt = Wtot0 / At: 'kg/jam/m^2
```

```
'Pendingin
Wp = 180000: 'kg/jam
Gp = Wp / ASs: 'kg/jam/m^2

PRINT : PRINT
PRINT "Spesifikasi Reaktor Fixed Bed Multitubes"
PRINT "~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~"
PRINT "Diameter Luar Tube   :"; TAB(25); OD; TAB(36); "meter"
PRINT "Diameter Dalam Tube  :"; TAB(25); ID; TAB(36); "meter"
PRINT "Triangular Pitch     :"; TAB(25); Pt; TAB(36); "meter"
PRINT "Clearance            :"; TAB(25); Cl; TAB(36); "meter"
PRINT "Diameter Dalam Shell :"; TAB(25); IDs; TAB(36); "meter"
PRINT "Jarak Buffle         :"; TAB(25); Bs; TAB(36); "meter"
PRINT "Jumlah Tube          :"; TAB(25); Nt

PRINT : PRINT "Kondisi Masuk reaktor"
PRINT "~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~"
PRINT "Temperatur umpan           ="; Tf; "K"
PRINT "Temperatur Pendingin Masuk  ="; Tpf; "K"
PRINT "Tekanan                     ="; Pf; "Atm": PRINT
INPUT "Tekan Enter......"; ENT$

PRINT STRING$(60, "=")
PRINT "  Komponen       Kec.Alir(kg/jam)        Kec.Alir(kmol/jam"
PRINT STRING$(60, "-")
PRINT USING "Etilen          = ####.####"; W10;
PRINT USING "   ###.####"; F10
PRINT USING "Air       = ####.####"; W20;
PRINT USING "   ###.####"; F20
PRINT USING "Etana               = ####.####"; W30;
PRINT USING "   ###.####"; F30
PRINT USING "Etanol       = ####.####"; W40;
PRINT USING "   ###.####"; F40
PRINT STRING$(60, "-")
PRINT USING "Umpan Total        = ####.####"; Wtot0;
PRINT USING "   ###.####"; Ftot0
PRINT STRING$(60, "=")
INPUT "Tekan enter..."; ENT$

'Fraksi Mol Gas Awal
Ym10 = F10 / Ftot0: Ym20 = F20 / Ftot0: Ym30 = F30 / Ftot0:
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```
Ym40 = F40 / Ftot0
Ymcamp0 = Ym10 + Ym20 + Ym30 + Ym40

'Berat campuran Gas Awal,kg/kmol
BMcampa = Ym10 * BM(1) + Ym20 * BM(2) + Ym30 * BM(3)
BMcamp0 = BMcampa + Ym40 * BM(4)

'Densitas Campuran Gas Awal
Rhocamp0 = Pf * BMcamp0 / R / Tf

'Vb&Tb
'Vb(1) = 37: Vb(2) = 59.2: Vb(3) = 14.8: Vb(4) = 96.2: Vb(5) = 51.8: Vb(6) =
'Tb(1) = 189: Tb(2) = 390.9: Tb(3) = 373: Tb(4) = 345.8: Tb(5) = 293.4: Tb(6)

'Viskositas Campuran Gas Awal,kg/m/jam
atasa = 0: bawaha = 0

Myu0(1) = .1206: Myu0(2) = .27936: Myu0(3) = .2646: Myu0(4) = .3852
atasa = atasa + Ym10 * Myu0(1) * BM(1) ^ .5 + Ym20 * Myu0(2) * BM(2) ^ .5
atasa = atasa + Ym30 * Myu0(3) * BM(3) ^ .5 + Ym40 * Myu0(4) * BM(4) ^ .5

bawaha = bawaha + Ym10 * BM(1) ^ .5 + Ym20 * BM(2) ^ .5 + Ym30 * BM(3) .5
bawaha = bawaha + Ym40 * BM(4) ^ .5
Myucamp0 = atasa / bawaha

PRINT : PRINT
PRINT "BM Campuran     ="; TAB(15); BMcamp0; TAB(26); "kg/kmol"
PRINT "Densitas        ="; TAB(15); Rhocamp0; TAB(26); "kg/m^3"
PRINT "Viskositas      ="; TAB(15); Myucamp0; TAB(26); "kg/m/jam"
PRINT "Perbandingan Mol Etilen terhadap Air="; F10 / F20
PRINT : PRINT
PRINT STRING$(61, "=")
PRINT " z(m)    x1        T(K)    Tp(K)   P(atm)"
PRINT STRING$(61, "-")
A$ = "##.###   #.####     ###.###  ###.###  ##.####"
z0 = 0: x10 = 0:  T0 = Tf: Tp0 = Tpf: P0 = Pf: dz = .05

1000
z = z0: x1 = x10:  T = T0: Tp = Tp0: P = P0
GOSUB 2000
iprint = I / 2
IF iprint = INT(iprint) THEN PRINT USING A$; z; x1; T; Tp; P
```

```
drop dalar

drop dalar
ENT$
)
Kec.Alir,ki
 = ###.#
##"; W1
###.####'
##"; W2
 = ##
##"; W3
 = ###.###
##"; W4

al = #
##"; Wtot

ENT$

gas
ran gas
mpuran g

onversi x
M(1)
BM(2)
M(3)
BM(4)

/4
/ Ftot:

gas ca
+ Ym2
4 * BI
/ T
```

```
A1 = dx1dz * dz:
C1 = dtdz * dz: D1 = dtpdz * dz: E1 = dpdz * dz
z = z0 + dz / 2: x1 = x10 + A1 / 2:
T = T0 + C1 / 2: Tp = Tp0 + D1 / 2: P = P0 + E1 / 2
GOSUB 2000

A2 = dx1dz * dz:
C2 = dtdz * dz: D2 = dtpdz * dz: E2 = dpdz * dz
z = z0 + dz / 2: x1 = x10 + A2 / 2:
T = T0 + C2 / 2: Tp = Tp0 + D2 / 2: P = P0 + E2 / 2
GOSUB 2000

A3 = dx1dz * dz:
C3 = dtdz * dz: D3 = dtpdz * dz: E3 = dpdz * dz
z = z0 + dz: x1 = x10 + A3:
T = T0 + C3: Tp = Tp0 + D3: P = P0 + E3
GOSUB 2000

A4 = dx1dz * dz:
C4 = dtdz * dz: D4 = dtpdz * dz: E4 = dpdz * dz
z = z0 + dz

x1 = x10 + ((A1 + 2 * A2 + 2 * A3 + A4) / 6)
T = T0 + ((C1 + 2 * C2 + 2 * C3 + C4) / 6)
Tp = Tp0 + ((D1 + 2 * D2 + 2 * D3 + D4) / 6)
P = P0 + ((E1 + 2 * E2 + 2 * E3 + E4) / 6): I = I + 1
IF x1 > .23 THEN 1500
z0 = z: x10 = x1:
T0 = T: Tp0 = Tp: P0 = P
GOTO 1000

1500
z = z0: x1 = x10:  T = T0: Tp = Tp0: P = P0
PRINT USING A$; z; x1; T; Tp; P
PRINT STRING$(61, "=")
INPUT "Tekan enter....."; ENT$
PRINT : PRINT
PRINT "Kondisi Setelah Keluar reaktor:"
PRINT "~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~"
PRINT USING "suhu gas keluar reaktor          = ###.#### K"; T
PRINT USING "Suhu pendingin masuk reaktor     = ###.#### K"; Tp
PRINT USING "Konversi reaksi  keluar reaktor  =  #.####"; x1
```

/jam
Bs / .304
Des / .3
s * (12 *

====== =
l Bed M

252125
----

l Multit

```
'Viskositas gas,kg/m/jam
atas1 = 0: bawah1 = 0
Myu(1) = .1206: Myu(2) = .27936: Myu(3) = .2646: Myu(4) = .3852
atas1 = atas1 + Ym1 * Myu(1) * BM(1) ^ .5 + Ym2 * Myu(2) * BM(2) ^ .5
atas1 = atas1 + Ym3 * Myu(3) * BM(3) ^ .5 + Ym4 * Myu(4) * BM(4) ^ .5

bawah1 = bawah1 + Ym1 * BM(1) ^ .5 + Ym2 * BM(2) ^ .5 + Ym3 * BM(3) ^ .5
bawah1 = bawah1 + Ym4 * BM(4) ^ .5
Myucamp = atas1 / bawah1

'Kapasitas panas gas,kkal/kmol/K
cpgcamp = 0: cpg2camp = 0: fcp = 0
cpg(1) = .2389 * (40.75 + .1147 * Tf - 6.891E-05 * (Tf ^ 2) + 1.766E-08 * (Tf^3))
cpg(2) = .2389 * (33.46 + .00688 * Tf + 7.604E-06 * (Tf ^ 2) - 3.593E-09 *(Tf^3))
cpg(3) = .2389 * (49.37 + .1392 * Tf - 5.816E-05 * (Tf ^ 2) + 7.28E-09 * (Tf ^3))
cpg(4) = .2389 * (61.34 + .1572 * Tf - 8.749E-05 * (Tf ^ 2) + 1.983E-08 * (Tf^3))
nidji = Ym1 * cpg(1) + Ym2 * cpg(2) + Ym3 * cpg(3)
cpgcamp = nidji + Ym4 * cpg(4)
cpg2camp = cpg2camp + Ym1 * cpg(1) / BM(1) + Ym2 * cpg(2) / BM(2)+
Ym3cpg
cpg2camp = cpg2camp + Ym4 * cpg(4) / BM(4)
fcp = pcp + F1 * cpg(1) + F2 * cpg(2) + F3 * cpg(3) + F4 * cpg(4)
'Konduktivitas panas gas,kkal/jam/m/K
atas2 = 0: bawah2 = 0

K(1) = .2389 * Myu(1) * ((cpg(1) / .2389 / BM(1)) + 10.4 / BM(1))
K(2) = .2389 * Myu(2) * ((cpg(2) / .2389 / BM(2)) + 10.4 / BM(2))
K(3) = .2389 * Myu(3) * ((cpg(3) / .2389 / BM(3)) + 10.4 / BM(3))
K(4) = .2389 * Myu(4) * ((cpg(4) / .2389 / BM(4)) + 10.4 / BM(4))
atas2 = atas2 + K(1) * Ym1 * BM(1) ^ (1 / 2) + K(2) * Ym2 * BM(2) ^ (1 / 2)
atas2 = atas2 + K(3) * Ym3 * BM(3) ^ (1 / 2) + K(4) * Ym4 * BM(4) ^ (1 / 2)

bawah2 = bawah2 + Ym1 * BM(1) ^ (1 / 3) + Ym2 * BM(2) ^ (1 / 3) + Ym3 *
BM(3)
bawah2 = bawah2 + Ym4 * BM(4) ^ (1 / 3)
kcamp = atas2 / bawah2

'Viskositas,kapasitaspanas & konduktivitas pendingin,kg/m/jam
Myup = (35.5898 - .04212 * (Tp0f)) * 100 / 1000: 'kg/jam/m
cpp = (.11152 + .0003402# * Tp0f) * 100 / 1000: 'kkal/kg/K
kp = (1.512 - .0010387# * Tp0f) * 100 / 1000: 'kkal/jam/m/K
```

Tekan Enter......?

Komponen	Kec.Alir(kg/jam)	Kec.Alir(kmol/jam
Etilen	= %14943.2891	533.6889
Air	= 8005.3325	444.7407
Etana	= 36.1080	1.2036
Etanol	= 0.0000	0.0000
Umpan Total	= %22984.7305	979.6332

Tekan enter...?

z(m)	x1	T(K)	Tp(K)	P(atm)
0.000	0.0000	523.000	520.000	68.0000
0.100	0.0050	524.528	519.837	68.0000
0.200	0.0100	525.968	519.362	68.0000
0.300	0.0151	527.323	518.593	68.0000
0.400	0.0202	528.600	517.546	67.9999
0.500	0.0254	529.802	516.238	67.9999
0.600	0.0306	530.935	514.685	67.9999
0.700	0.0358	532.001	512.900	67.9999
0.800	0.0410	533.006	510.897	67.9999
0.900	0.0463	533.952	508.688	67.9999
1.000	0.0516	534.843	506.286	67.9998
1.100	0.0570	535.682	503.702	67.9998
1.200	0.0623	536.473	500.946	67.9998
1.300	0.0677	537.217	498.028	67.9998
1.400	0.0731	537.919	494.958	67.9998
1.500	0.0786	538.579	491.745	67.9998
1.600	0.0840	539.202	488.397	67.9998
1.700	0.0895	539.788	484.921	67.9997
1.800	0.0950	540.340	481.326	67.9997
1.900	0.1005	540.860	477.618	67.9997
2.000	0.1060	541.350	473.803	67.9997
2.100	0.1116	541.811	469.888	67.9997
2.200	0.1171	542.246	465.879	67.9997
2.300	0.1227	542.655	461.781	67.9996
2.400	0.1283	543.041	457.599	67.9996
2.500	0.1338	543.404	453.339	67.9996
2.600	0.1394	543.746	449.004	67.9996

SPESIFIKASI REAKTOR

1. Spesifikasi Tube:

Susunan pipa: triangular pitch

Nominal Pipe Size (IPS)	: 1,5 in
Outside Diameter (OD)	: 4,826 cm
Inside Diameter (ID)	: 4,0894 cm
Sch No	: 40
Surface per lin ft	
Inside	: 0,422 ft^2/ft
Outside	: 0,498 ft^2/ft
Pitch	: 6,0325 cm
Clearance	: 1,2065 cm

2. Menghitung Tebal Shell

Dipilih material Carbon Steel SA – 285 Grade C karena cocok untuk tekanan tinggi. (table 13.1 Brownell 'n Young)

Tekanan desain reaktor

P	= 1,1 atm
Allowable Stress (S)	= 13750 psi
Efisiensi sambungan (e)	= 0,8 (double welded butt join)
Faktor korosi (C)	= 0,125 inch
Jari-jari tangki (ri)	= 21,5944 inch

$$T\ shell = \frac{P.ri}{f.E - 0{,}6P} + C$$

$$= \frac{1{,}1 \times 21.5944}{13750 \times 0{,}8 - 0{,}6 \times 19.404} + 0{,}125$$

$$= 0.163132961 \text{ inch}$$

Dipakai tebal shell standar 3/16 inch

3. Menghitung Tebal Head

Bentuk Head Eliptical, Dished Head 2 : 1 (Elipzoidal) karena cocok tekanan tinggi. Digunakan bahan carbon steel SA-285 grade C

Tekanan reaktor (P)	: 19.404 psi
Allowable Sambungan (e)	: 0,8 (double welded butt joint)
Faktor Korosi (C)	: 0,125 inch
Jari-jari Tangki (ri)	: 62,3631 inch

Tebal head : $\frac{0.885 P.ri}{F.E - 0{,}1P} + C$

: $\frac{0.885 x 19.404 x 62.3631}{13750 \times 0{,}8 - 0{,}1 \times 19.404} + 0{,}125$

:0,00635 inch

Dipakai tebal head standar 0,25 inch

4. Menentukan ukuran Bed Reaktor

Diameter bed (D) = 3,168 m

Panjang katalis (L) = 4.150 m

L/D = 2,97

Tinggi Bed

= (L/D) x diameter bed

= 2,97 . 3,168 = 9,41 m

Ruang kosong pada bagian atas shell = 1 m

Ruang kosong pada bagian bawah shell = 0,5 m

Tinggi reaktor = panjang tube + 2 tinggi head

= 163.386 + (2 x 14.4319) m

= 4.8831 m

Tinggi reaktor keseluruhan = tinggi reaktor + tinggi head + tinggi dishead

= (4.8831 + 0,8619 + 0,8619) m

= 4.8831 m

5. Menghitung Ukuran Pipa

a. Pipa pemasukan umpan reaktor

Bahan carbon steel

Kecepatan umpan = 37000,971 kg/jam x 2,2 lb/kg

= 81402,1362 lb/jam

densitas umpan (ρv) $= \dfrac{P.BMrata - rata}{RT}$

$= \dfrac{68 \times 23{,}4625}{82{,}06 \times 523} 62{,}43 = 2{,}47\ lb/ft^3$

BMavg $= \dfrac{62530{,}0632}{96200{,}1971}(28) \times \dfrac{3126{,}5031}{96200{,}0971}(30) \times \dfrac{30543{,}5302}{96200{,}0971}(18)$

$= 24{,}9747$

Di $= 2{,}2\ (G/1000)^{0,45}.\rho v^{-0,31}$

$= 2{,}2\ (211{,}6402)^{0,45}.2{,}47^{-0,31}$

$= 18{,}5026$ in

jadi digunakan pipa dengan ukuran = 20 in

b. Pipa Pengeluaran Hasil Reaktor

Bahan Carbon Steel

Kecepatan hasil = 211640,2136 lb/jam

Densitas umpan $= \dfrac{P.BMrata - rata}{RT}$

$= \dfrac{67{,}93 \times 26{,}0787}{82{,}06 \times 578{,}6493} \times 62{,}43 = 2{,}33\ lb/ft^3$

Di $= 2{,}2\ (G/1000)^{0,45}.\rho v^{-0.31}$

$= 2{,}2\ (211{,}6402)^{0,45}.2{,}33^{-0,31} = 18{,}8381$ in

jadi digunakan pipa dengan ukuran = 20 in

6. Spesifikasi Baffle

Jenis : Segmental Baffle

Baffle Space : 0,25 x diameter shell

: 0,25 x 109.6998 cm = 79,2012 cm

Jumlah Baffle : panjang katalis/baffle space

: 9,41 m / 0,79 m = 11,91

dipilih jumlah baffle : 12

7. Volume Reaktor

a. Volume Reaktor

$V\,h = 0{,}000049.D_{shell}^{3}$

$= 0{,}000049 \times (1.0970\ m)^{3}$

$= 0{,}0254\ m^{3}$

b. Volume Badan Reaktor

$V\,b = \frac{\pi}{4}.\ D_{shell}^{2}.L$

$= \frac{3{,}14}{4} \times (1.0970\ m)^{2} \times 4.150\ m$

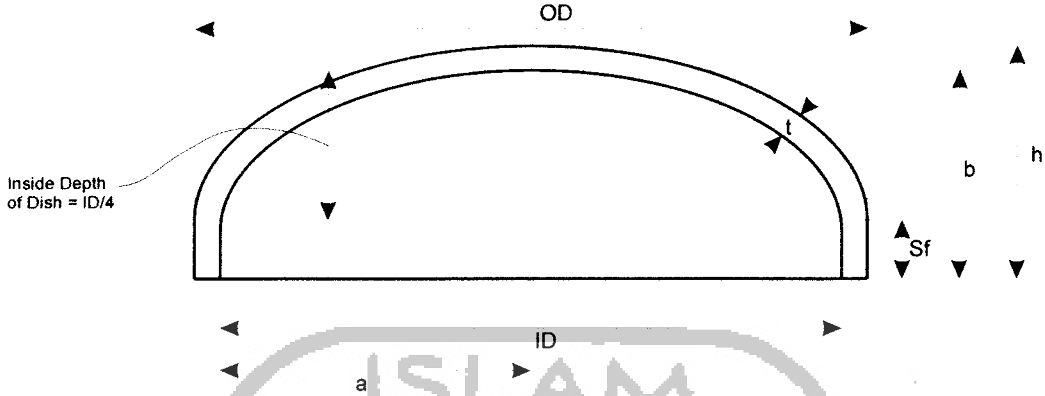
$= 2{,}8345\ m^{3}$

c. Volume Total Reaktor

$V = 2.Vh + Vb$

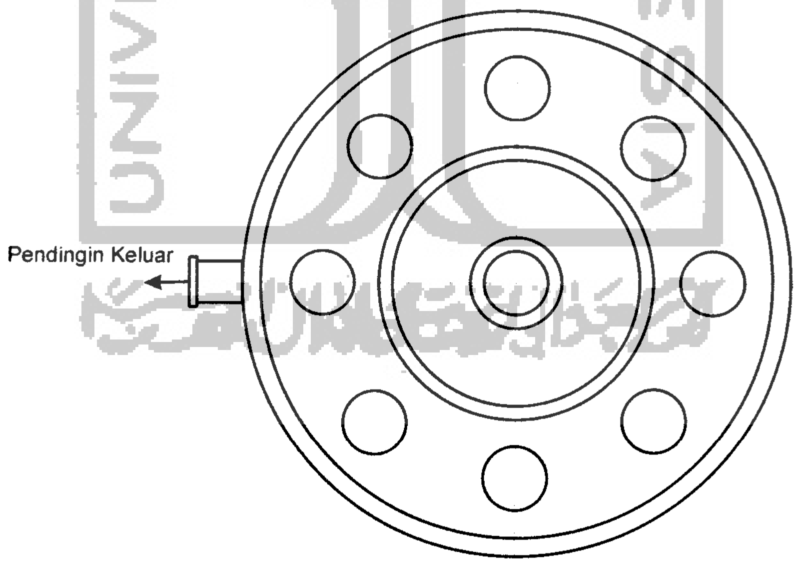
$= 2\ (0{,}0024) + 74{,}1737$

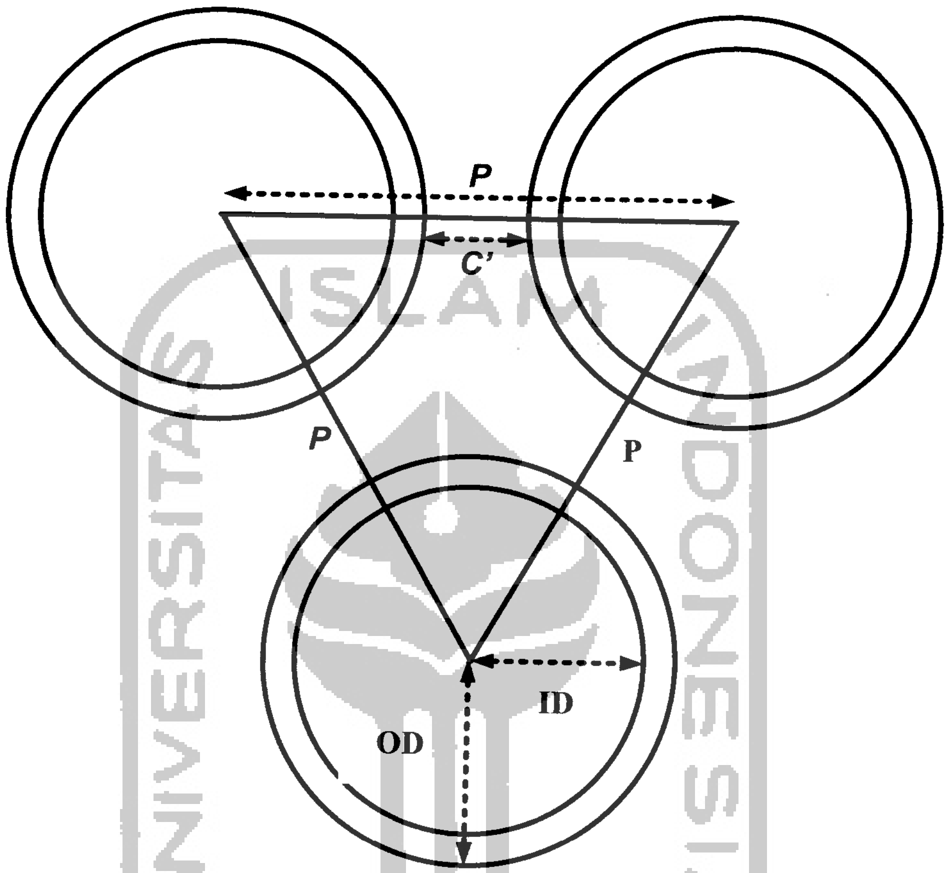
$= 2.8347\ m^{3}$



Gambar Head/Dished

Bentuk: elliptical/ellipzoidal
Bahan: Carbon Steels SA-285 Grade C
ID = Inside Diameter: 124.7262 in
OD = Outside Diameter: 125.2262 in
a = 0.5 ID = 62.3631 in
Sf = Straight Flange = 2.25 in
h = tinggi head = 33.9316 in
b = h - Sf = 31.6818 in
t = tebal head = 0.4251 in

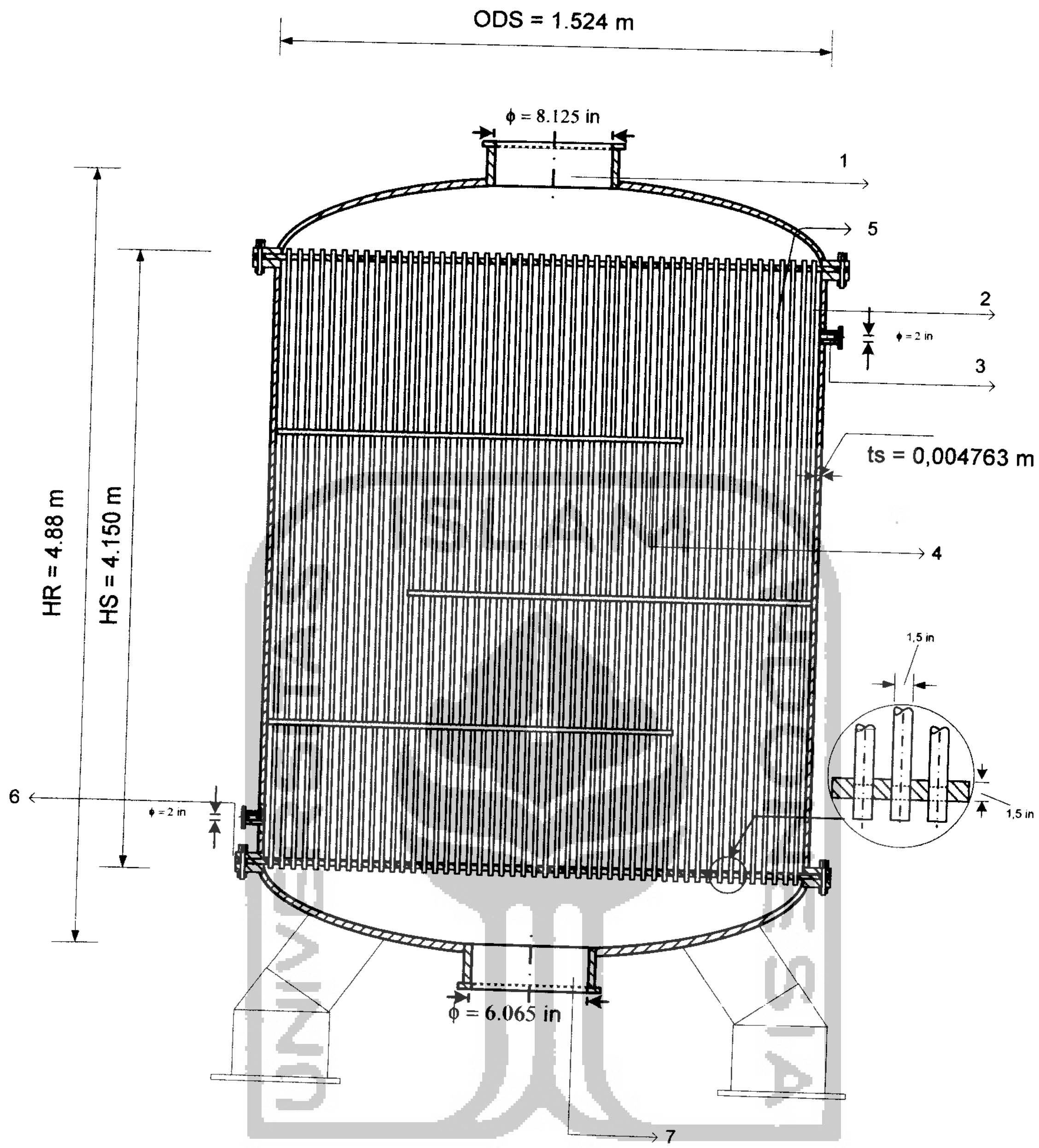




Gambar Susunan Pipa di Reaktor :

Keterangan :

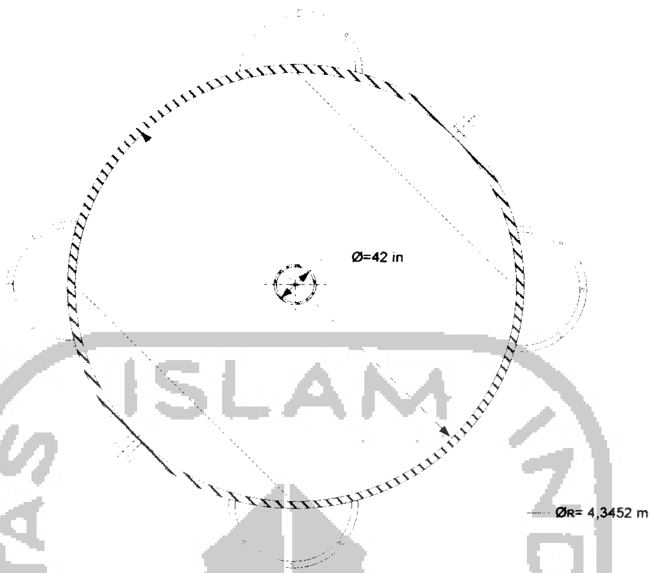
P : Pitch	(Jarak antar diameter)	= 6.0325	cm
Cl : Clearance	(Jarak antar pipa)	= 1.2065	cm
ID : Inside diameter	(Diameter dalam pipa)	= 4.0894	cm
OD : Outside diameter	(Diameter luar pipa)	= 4.826	cm



Gb. REAKTOR TAMPAK DEPAN

Keterangan Gambar Reaktor :

1. Pipa masuk umpan
2. Tube Reaktor
3. Pipa Pendingin keluar
4. Clearance
5. Pitch
6. Pipa Pendingin masuk
7. Pipa Gas reactor keluar



Gb. Reaktor Tampak Atas