## PERANCANGAN ALAT UTAMA

Nama alat : Reaktor
Kode : R-110

**Dasar Perancangan**

Fungsi :

Sebagai tempat untuk mereaksikan Etanol (C2H6O) dengan Asam Sulfat (

Perlengkapan :
- Pengaduk
- Jaket pendingin
- Sparger

Reaksi yang terjadi :
- Reaksi I

$$C_2H_6O + H_2SO_4 \rightarrow$$

- Reaksi II

$$C_2H_6SO_4 + C_2H_5OH \rightarrow$$

Tipe : Mixed Flow Reactor

Tutup Reaktor : Tangki berbentuk silinder tegak dengan tutup atas standar dished dan tutup
120□

Kondisi Operasi :

| | | | | |
|---|---|---|---|---|
| - | Temperatur | = | 127 | $^oC$ = |
| - | Tekanan | = | 2100 | kpa = |
| - | Waktu operasi | = | 30 | menit = |
| - | Fase | = | Gas-Liquid | |
| - | Reaksi | = | Eksotermis | |
| - | Feed bahan masuk | = | 19278.7253 | |
| | | = | 42502.26 | lb/ja |
| | | = | 11.8062 | lb/d |

**Direncanakan**

- Bahan konstruksi : High Alloy steel SA 240 Grade M type 316
- Allowable stress (f) : 18750 (APP D. I
- Tipe pengelasan : Double welded butt joint
- E : 0.8 (Brownel
- Faktor korosi ( C ) : 1/16 in = 0.0625 in

**Komponen masuk reaktor**

| Komponen | BM (kg/kmol) | Rate | | |
|---|---|---|---|---|
| | | kg/jam | kgmol/jam | |
| C2H6O | 74.1252 | 9064.895583 | 122.2918 | Etan |
| H2O | 18.0150 | 477.0997675 | 26.4835 | |
| H2SO4 | 98.0800 | 9347.260752 | 95.3024 | Asam Sul |
| H2O | 18.0150 | 389.469198 | 21.6192 | |

| | | | |
|---|---|---|---|
| Total | 208.235157 | 19278.725 | 265.6968 |

Komposisi Bahan Masuk

- H2SO4 = 9736.72995 kg/jam =
- Gas Masuk = 9542.00 kg/jam =

**Menentukan densitas campuran**

| Komponen | Massa (kg/jam) | xi (massa) | □ (lb/ft$^3$) | |
|---|---|---|---|---|
| C2H6O | 9064.8956 | 0.4702 | 42.2784 | |
| H2O | 477.0998 | 0.0247 | 57.9186 | |
| H2SO4 | 9347.2608 | 0.4848 | 106.4029 | |
| H2O | 389.4692 | 0.0202 | 57.9186 | |
| Total | 19278.7253 | 1.0000 | 264.5185 | |

(data densitas diperoleh dari Yaws, density of liquid Hal.185 dan Engineering Toolbox)

$$\rho \text{ campuran} = \frac{\sum xi.\rho i}{\sum xi} = \frac{74.0721}{1.0000} = 74.072$$

( Dikutip dari Yaws, Tabel 21-1 ) $\mu = A+BT+CT2$

| **Komponen** | **A** | **B** | **C** | **μ (Cp)** |
|---|---|---|---|---|
| C2H6O | -6.4406 | 1117.600 | 0.0137 | 449.398 |
| $H_2O$ | -10.2158 | 1792.500 | 0.0177 | 720.098 |
| H2SO4 | -18.7045 | 3496.200 | 0.0331 | 1404.28 |
| H2O | -10.2158 | 1792.500 | 0.0177 | 720.098 |
| Total | | | | 3293.88 |

**Menentukan viskositas campuran**

| Komponen | Massa (kg/jam) | xi (massa) | □ (Cp) | |
|---|---|---|---|---|
| C2H6O | 9064.8956 | 0.4702 | 449.3982 | |
| H2O | 477.0998 | 0.0247 | 720.0976 | |
| H2SO4 | 9347.2608 | 0.4848 | 1404.2825 | |
| H2O | 389.4692 | 0.0202 | 720.0976 | |
| Total | 19278.7253 | 1.0000 | 3293.8759 | |

(data densitas diperoleh dari Yaws, Viscosity of liquid and gas Hal 483 dan 501)

$$\mu \text{ campuran} = \frac{\sum xi.\mu i}{\sum xi}$$

$$= \frac{0.62126}{1.000} = 0.6213 \text{ lb/ft.s} = 2236.5$$

Bahan masuk = 19278.73 kg/jam = 42502.26

**Menentukan Volume Reaktor**

Dengan Rumus,

$$Vgas = \frac{n \times R \times T}{P}$$

(karena reaksi dengan suhu tinggi dan tekanan tinggi (Eksoterm))

Dimana,

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| P | : | Tekanan Operasi | = | 14.6959 | psia | = | 1489062.07 |
| n | : | Rate Massa | = | 265.697 | kgmol/jam | | |
| R | : | Konstanta Gas Ideal | = | 831447 | .Pa/ Kgmol.K | | |
| T | : | Temperatur | = | 127 | C | | |
| | | | = | 259.6 | F | | |
| | | | = | 719.6 | R | | |
| | | | = | 400.2 | K | | |

$$Vgas = \frac{n \times R \times T}{P}$$

$$= \frac{265.6968 \times 831447 \times 400.15}{1489062.068}$$

$$= 59365.1 \text{ m3/ jam}$$

$$= 16.4903 \text{ m3/ detik}$$

**Menentukan Waktu Reaksi**

Mencari CaO

$$CaO = \frac{P}{R \times T}$$ (*Levenspiel*, Pers. 2 hal. 39)

Dimana,

| | | | | | |
|---|---|---|---|---|---|
| P | : | Tekanan | = | 1489062 | Pa |
| R | : | Konstanta | = | 831447 | .Pa/ Kmol.K |
| T | : | Temperatur | = | 400.15 | K |

$$CaO = \frac{P}{R \times T}$$

$$CaO = \frac{1489062}{831447 \times 400.15}$$

$$= 0.0044756 \text{ Kmol/ m3}$$

$$= 4.4756E\text{-}06 \text{ Kmol/ L}$$

$$FaO = \frac{11.2754}{1186.52424}$$

$$= 0.00950288$$

$$\tau = \frac{V}{Vo} = \frac{VCaO}{FaO}$$ (*Levenspiel*, Pers.17 hal.102)

(basis volume waktu = 1 *second*)

$$\tau = \frac{V \times CaO}{FaO}$$

$$= \frac{16.5 \times 0.00448}{0.009502882}$$

$$= 7.76655619 \text{ detik}$$

$$= 0.00215738 \text{ jam}$$

**Menentukan Konstanta Kecepatan Reaksi (k)**

-rA = k.ca.Cb

= k.Ca2

= k.(CaO2)(1-Xa)^2

$$C_2H_6O + H_2SO_4 \rightarrow C_2H_5H_2SO_4 + H_2O$$

Vxa = 0 95% Vxa = 1

$$A + B \rightarrow C + D$$

196.764 212.452 90.53729 90.5373

$$\varepsilon A = \frac{VXA = 1 - Vxa = 0}{VXA = 0}$$

$$= \frac{\left(90.5372932 + 90.53729317\right) - 196.764}{181.0745863}$$

$$= \frac{181.074586 - 409.21599}{181.0745863}$$

$$= 1.2599$$

$$CAO\ k\tau = 2\varepsilon A(1+\varepsilon A)\ln(1+XA) + \varepsilon 2A.XA$$

$$0.00272 = -18.33056761 + 1.523927968$$

$$k = 0.018024614$$

**Menentukan Volume Liquid (V1)**

- Densitas Liquid = 40.3475 $lb/ft^3$
- Rate Liquid (v0) = 20606.9711 lb/jam

40.3475 $lb/ft^3$

= 510.7370 $ft^3$/Jam

- Dari Levenspiel persamaan 8 halaman 101, didapatkan :

$$\tau = \frac{V}{v0}$$

$$0.0022 = \frac{V}{510.7370}$$

$$V = 1.1019\ ft^3$$

**Menentukan Volume Gas**

- Densitas Gas = 0.8641 $lb/ft^3$
- Rate Gas (v0) = 21036.2829 lb/jam

$$= \frac{}{0.8641} \quad lb/ft^3$$

$$= 24344.7320 \quad ft^3/Jam$$

- Dari Levenspiel persamaan 8 halaman 101, didapatkan :

$$\tau = \frac{V}{v0}$$

$$0.0022 = \frac{V}{24344.7320}$$

$$V = 52.5208 \quad ft^3$$

**6.1 Rancangan Dimensi Reaktor**

**A Volume Reaktor**

- Volume Liquid = 1.1019 $ft^3$

- Asumsi Ruang Kosong = 30%
- V Total = V Liquid + V Ruang Kosong

  V Total = 1.1019 + 30% V Total

  0.7 V Total = 1.1019 $ft^3$

  V Total = 1.5741 $ft^3$
- V Ruang Kosong = 30% V Total

  = 30% x 1.5741 $ft^3$

  = 0.4722 $ft^3$

**B. Menentukan Dimensi Reaktor**

1. Menghitung diameter Reaktor

   Asumsi Ls = 1.5 di

   Tutup Bawah = Tutup Atas = Standard Dished

   V Total = V Tutup Bawah + V Silinder + V Tutup Atas

   1.5741 = 0.0847 $di^3$ + $\frac{\pi . Di^2 . Ls}{4}$ + 0.0847 $di^3$

   1.5741 = (2 x 0.0847 $di^3$) + $\frac{\pi . Di^2 . 1{,}5\ di}{4}$

   1.5741 = 0.1694 $di^3$ + 1.1775 $di^3$

   1.5741 = 1.3469 $di^3$

   di = 1.0533 ft

   di = 12.6399 in

2. Menentukan Volume Liquid dalam silinder

   Vliq dalam Silinder = Vliq - V Tutup bawah

   = 1.1019 - 0.0990

   = 1.0029 $ft^3$

3. Menentukan Tinggi Liquid dalam Tangki

   V Liquid = V Tutup Bawah + Vliquid Dalam Silinder

   1.1019 = 0.0990 + $\frac{\pi . Di^2 . Lls}{4}$

   1.0029 = 0.87096 Lls

Lls = 1.1515 ft
Lls = 13.8175 in

4. Menentukan Tekanan Design (Pi)
Tekanan Design (Pi) = Tekanan Operasi ($P_{Operasi}$)
= 14.6959 psia

5. Menentukan tebal silinder (ts)
Tebal silinder (ts) = $\frac{Pi \times di}{2(fE - 0{,}6\ Pi)} + C$

= $\frac{14.6959 \times 12.6399}{18750 \times 0.8 - 0.6 \times 14.7 \times}$

= $\frac{185.7551}{29982} + 0.063$

= 0.0062 + 0.063

= 29982.4 in x $\frac{16}{16}$ in

= $\frac{479718.8}{16}$ in ≈ $\frac{5}{16}$ in

Standarisasi do :
do = di + 2 ts
do = 12.6399 + 2 x $\frac{5}{16}$ in
do = 13.2649 in
do = 1.1054 ft

Dari Brownell and Young tabel 5.7 halaman 90 didapatkan:
do Tabel = 14 in
di baru = do - 2 ts
= 14 - 2 x $\frac{5}{16}$
= 13.3750 in
= 1.1146 ft

6. Menghitung tinggi silinder (Ls)
- V Total = V Tutup Bawah + V Silinder + V Tutup Atas
1.1019 = 0.0847 $di^3$ + $\frac{\pi . di^2 . Ls}{4}$ + 0.0847
1.1019 = 0.0847 2392.662 + 0.79 178.9 Ls +
Ls = 6.0665 ft
Ls = 6.0665 ft
Ls = 72.7983 in

- $\frac{Ls}{di} = \frac{72.798}{13.3750}$ = 5.4429 < 150 memenuhi

**C. Menentukan dimensi tutup atas (Standart dished)**

1. Menghitung dimensi tutup atas (standart dished )

Tebal tutup atas

- r = 14 (Brownell and Young halaman 89)
- icr = 7/8 (Brownell and Young halaman 89)
- sf = 1 1/2 (Brownell and Young halaman 88 )

$$tha = \frac{0{,}885 \times Pi \times di}{2(fE - 0{,}1\,Pi)} + C$$

$$= \frac{0.89 \times 14.6959 \times 13.3750}{18750 \times 0.8 - 0.1 \times 14.7 \times 2} + 0.063$$

$$= 0.0683$$

$$= \frac{1.0928}{16} \approx \frac{1}{16} \text{ in}$$

Tinggi Tutup Atas (ha)

ha = 0.169 x di

= 0.169 x 13.3750 in

= 2.2604 ft

= 27.125 in

Tutup atas dan tutup bawah sama maka :

tha = thb

ha = hb

tha = $\frac{1}{16}$ in maka, thb = $\frac{1}{16}$ in

ha = 27.125 in maka, hb = 27.125 in

Dari Perhitungan diatas, maka diperoleh dimensi reaktor sebagai berikut:

- Diameter Luar (do) = 13.2649 in
- Diameter Dalam (di) = 13.3750 in
- Tinggi Silinder (Ls) = 72.7983 in
- Tebal tutup atas (tha) = 1/16. in
- Tinggi tutup atas (ha) = 27.1245 in
- Tebal tutup bawah (thb) = 1/16. in
- Tinggi tutup bawah (hb) = 27.1245 in
- Tinggi reaktor (H) = Tinggi (tutup atas +silinder +tutup bawah) +s

= 208.4208 in

= 17.3684 ft

= 5.2939 m

**6.3. Perhitungan Jacket Pendingin**

**Menentukan $\Delta T_{LMTD}$**

Suhu masuk feed ($T_1$) = 127 □C = 260.6

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Suhu masuk feed ($T_2$) | | | | | = | 127 | □C | = | 260.6 |
| Suhu masuk pendingin ($t_1$) | | | | | = | 27 | □C | = | 80.6 |
| Suhu keluar Pendingin ($t_2$) | | | | | = | 95 | □C | = | 203 |
| $\Delta t_1$ | = | T1 - t2 = | 260.6 | - | 203 | = | 57.6 | □F | |
| $\Delta t_2$ | = | T2 - t1 = | 260.6 | - | 80.6 | = | 180 | □F | |

$$\Delta T_{LMTD} = \frac{\Delta t_1 - \Delta t_2}{\ln \frac{\Delta t_1}{\Delta t_2}} = \frac{57.6 - 180}{\ln \frac{57.6}{180}} = \frac{-122}{-1.1394}$$

$\Delta t = \Delta T_{LMTD} \times Ft$

$\Delta t = 107.422 \times 1$

$\Delta t = 107.422$ °F

**Menentukan Luas Perpindahan Panas**

Nilai UD Berdasarkan Kern halaman 840 bagian coolers yaitu 75-150

$$A = \frac{Q}{UD \cdot \Delta t} = \frac{141346.0527}{120 \times 107.422} = 10.9650 \text{ ft}^2$$

(nilai A<120 $ft^2$, maka menggunakan Jaket )

Dalam reaktor terjadi reaksi eksotermis, maka reaktor dilengkapi jaket dengan air pendingin sebagai media pendinginnya.

| | | | | | | |
|---|---|---|---|---|---|---|
| Rate massa air pendingin | = | 2268515.3818 | kg/jam | = | 5 | |
| Densitas air pendingin | = | 995.6800 | $kg/m^3$ | = | | |
| Laju alir air | = | $\frac{5001169.011}{62.1304}$ | | | | |
| | = | 80494.6763 | $ft^3$/jam | | | |
| Volume air yang dibutuhkan | = | 80494.6763 | x | 0.0022 | | |
| | = | 173.6575 | $ft^3$ | | | |
| Volume air pendingin total | = | Volume air yang dibutuhkan +10% excess | | | | |
| | = | 173.6575 | + | 0.1 | 173 | |
| | = | 191.0232 | $ft^3$ | | | |
| Tekanan dalam Reaktor | = | 1.000 | atm | | | |
| Diameter dalam tangki (di) | = | 13.3750 | in | = | 1.1146 | ft |
| Diameter luar tangki (do) | = | 13.2649 | in | = | 1.1054 | ft |
| Volume total tangki | = | 1.5741 | $ft^3$ | | | |
| Volume tutup bawah tangki | = | $\frac{\pi \, di^3}{24 \, tg \, 60}$ | | | | |
| | = | $\frac{4.3478}{41.5680}$ | | | | |
| | = | 0.1046 | $ft^3$ | | | |

Volume Liquid dalam silinder = 1.5741 - 0.1046

= 1.4695 $ft^3$

Luas alas silinder tangki = $\frac{\pi\ di^3}{24\ tg\ 60}$

= 0.1046 $ft^2$

Tinggi Liq dalam silinder (Lls) = $\frac{1.4695\ ft^3}{0.1046\ ft^2}$

= 14.0493 ft

**Menentukan Volume Silinder**

Volume tutup bawah tangki = $\frac{\pi\ do^3}{24\ tg\ 60}$

= $\frac{4.2413}{41.5680}$

= 0.1020

Volume Liquid dalam silinder = $\frac{\pi\ do^2\ Lls}{4}$

= 0.785 x 1.2219 x 14.049

= 13.4764 $ft^3$

Volume Liquida = Volume Liquid dalam silinder + Vol

= 13.4764 + 0.1020

= 13.5784 $ft^3$

Volume Jaket = Volume total air+ Volume Liquida +10%VolLiq

= 191.0232 + 13.5784 +

= 205.9595 $ft^3$

Asumsi nilai Ls = 1,5 di

Volume Jaket = Volume Liq dalam Silinder jaket + Vol

205.9595 = $\frac{\pi\ di^2\ Lls}{4} + \frac{\pi\ di^3}{24\ tg\ 60}$

205.9595 = $\frac{\pi\ di^2\ .\ 1{,}5\ di}{4} + \frac{\pi\ di^3}{24\ tg\ 60}$

205.9595 = 1.1775 $di^3$ + 0.07554 $di^3$

205.9595 = 1.2530 $di^3$

$di^3$ = 164.3680

di = 5.4778 ft

di = 65.7335 in

Volume bawah jaket = 0.075539 $di^3$

= 0.075539 x 164.3680

12.41617281 $ft^3$

hb = $\frac{0{,}5\ di}{}$

$$hb = tg\ 60 \times 1.5813 \text{ ft} = 18.97619375 \text{ in}$$

$$H = Ls + hb = 98.6003 + 1.5813 = 100.1817 \text{ ft} = 1202.179827 \text{ in}$$

Menentukan Pdesign = P operasi = 14.696 psia

**Menentukan tebal dinding jaket**

$$ts = \frac{Pi \times di}{2(fE - 0{,}6\ Pi)} + C$$

$$= \frac{14.6959 \times 13.3750}{\#\#\#\# \times 0.8 - 0.6 \times 14.7 \times 2} + 0.0625$$

$$= \frac{196.5577}{29982} + 0.0625$$

$$= 0.0066 + 0.0625$$

$$= 0.0691 \text{ in}$$

$$= \frac{1.1049}{16} \text{ in} \approx \frac{3}{16} \text{ in}$$

$$do = di + 2\ ts$$

$$= 13.3750 + 2\ \frac{3}{16} \text{ in}$$

$$= 13.7500 \text{ in}$$

standarisasi do baru pada Brownell and young halaman 92

do = 14

di = do - 2 ts

= 13.6250 in

= 1.13542 ft

Volume Jaket = Volume Liq dalam Silinder jaket + Volume tutup baw

$$205.9595 = \frac{\pi\ di^2\ Ls}{4} + \frac{\pi\ di^3}{24\ tg\ 60}$$

$$205.9595 = 1.0120\ Ls + 191.064522$$

$$Ls = 14.7183 \text{ ft}$$

$$Ls = 176.6201$$

$$\frac{Ls}{di} = \frac{14.7183}{13.6250} = 1.080245 < 2 \text{ memenuhi}$$

**Menentukan tebal tutup bawah jaket**

Bentuk bawah berbentuk standart dished

$$thb = \frac{0{,}885 \times Pi \times di}{2(fE - 0{,}1\,Pi)} + C$$

$$= \frac{0.89 \times 14.6959 \times 13.4}{\#\#\#\# \times 0.8 - 0.1 \times 14.7 \times 2} + 0.0$$

$$= 0.0683 \text{ in}$$

$$= \frac{1.0928}{16} \approx \frac{1}{16} \text{ in}$$

Tinggi Tutup Bawah (hb)

$$hb = 0.169 \times di$$

$$= 0.169 \times 13.3750 \text{ in}$$

$$= 2.2604 \text{ in}$$

$$= 0.1884 \text{ ft}$$

**Dari Perhitungan di atas diperoleh dimensi jaket sebagai berikut**

- Bahan Konstruksi = High Alloy Steels SA 240 Grade M typ
- Diameter luar (do) = 13.7500 in
- Diameter dalam (di) = 13.6250 in
- Tinggi Jaket (L) = 176.6201 in
- Tebal Jaket (ts) = 3/16. in
- Tebal Jaket tutup bawah (thb) = 3/16. in
- Tinggi jaket tutup bawah (hb) = 2.2604 in

## 6.3 Perhitungan untuk Sparger Udara

Dasar Perancangan

- Rate gas udara = 9541.9954 kg/jam = 21036.28
- Densitas Gas = 97.0000 $lb/ft^3$
- Suhu = 260.6000 °F
- P Gas = 14.696 psia

**Menghitung Luas Area Sparger**

Q (Rate Volumetrik) $= \frac{21036.2829}{97.0000} = 216.8689$ ft

$= 3.6145$ $ft^3$/menit

FPM = 25 (moot copration Hal 3)

ACFM (Luas Permukaan Sparger) $= 3.6145 \times \frac{14.7}{14{,}7 + P} \times \frac{460+}{520}$

$= 3.6145 \times 0.5001 \times 1.38$

$= 2.5048$ $ft^3$/menit

A (Luas Area Sparger) $= \frac{ACFM}{FPM}$

$$A = \frac{2.5048}{25.0000}$$

= 0.10019072 $ft^2$

A = 14.42746369 $in^2$

(www.Mott Corporation.com-sparger design

A = 1/4. π $D^2$

14.4275 = 0.7850 x $D^2$

$D^2$ = 18.3789 in

D = 4.28707 in

D = 0.35726 ft

**Trial jarak lubang agar harga At perhitungan sama dengan harga trial**

Jarak Antar Lubang, Pt = 0.5 in

Luas 1 segitiga = 1/2. (Pt, sin 60 ) Pt

= 0.5 x (0,75 x 0,866) x

= 0.108253 $in^2$

= 0.000752 $ft^2$

Luas Lubang Sparger (A) = $\frac{0.1002}{25}$

= 0.0040 $ft^2$

= 0.5771 $in^2$

A = 1/4. π $D^2$

0.5771 = 0.7850 x $D^2$

$D^2$ = 0.735157 in

D = 0.857413 in

D = 0.071451 ft

Menentukan Jumlah Lubang Sparger

Jumlah Lubang = $\frac{A}{A\ Segitiga}$

= $\frac{0.1002}{0.0040}$

= 25.000 ≈ 25 buah

**6.4a Perhitungan Shower H2SO4**

Dasar Perancangan

- Rate feed cairan = 21465.595 kg/jam = 47323.05
- Densitas Cairan = 49.1636 $lb/ft^3$
- Suhu = 260.6000 °F
- P Gas = 14.696 psia

**Menghitung Luas Area Shower**

Q (Rate Volumetrik) = $\frac{47323.0504}{49.1636}$ = 962.5628 $ft^3$/jam

= 16.0427 $ft^3$/menit

FPM = 25 (moot copration Hal 3)

ACFM (Luas Permukaan Shower) = 16.0427 x $\frac{14.7}{}$ x $\frac{460+T}{}$

$$= 16.0427 \times \frac{14,7 + P}{0.5001} \times \frac{520}{1.3858}$$

$$= 11.1173 \text{ ft}^3/\text{menit}$$

A (Luas Area Shower)

$$= \frac{\text{ACFM}}{\text{FPM}}$$

$$A = \frac{11.1173}{25.0000}$$

$$= 0.4447 \text{ ft}^2$$

$$A = 64.0356 \text{ in}^2$$

(moot copration Hal 3)

$$A = 1/4.\ \pi\ D^2$$

$$64.0356 = 0.7850 \times D^2$$

$$D^2 = 81.5741 \text{ in}$$

$$D = 9.03184 \text{ in} \quad \text{ft}$$

$$D = 0.75265 \text{ ft}$$

**Trial jarak lubang agar harga At perhitungan sama dengan harga trial**

Jarak Antar Lubang, Pt = 0.5 in

Luas 1 segitiga = 1/2. (Pt, sin 60 ) Pt

$$= 0.5 \times (0,75 \times 0,866) \times 0.$$

$$= 0.108253 \text{ in}^2$$

$$= 0.000752 \text{ ft}^2$$

Luas Lubang Shower (A)

$$= \frac{0.4447}{25}$$

$$= 0.0178 \text{ ft}^2$$

$$= 2.5614 \text{ in}^2$$

$$A = 1/4.\ \pi\ D^2$$

$$2.5614 = 0.7850 \times D^2$$

$$D^2 = 3.262963 \text{ in}$$

$$D = 1.806367 \text{ in}$$

$$D = 0.150531 \text{ ft}$$

Menentukan Jumlah Lubang Shower

$$\text{Jumlah Lubang} = \frac{A}{A \text{ Segitiga}}$$

$$= \frac{0.4447}{0.0178}$$

$$= 25.000 \approx 25 \text{ buah}$$

## 6.5. Perhitungan Nozzle

**Dasar Perencanaan :**

a. Nozzle pada tutup standart dished

- Nozzle untuk pemasukan larutan H2SO4

- Nozzle untuk pengeluaran gas produk

b. Nozzle pada jaket pendingin
- Nozzle untuk Ma*nhole*
- Nozzle untuk pemasukan dan pengeluaran air pendingin

c. Nozzle pada tutup bawah conical
- Nozzle untuk pengeluaran campuran Asam Asetat
- Nozzle untuk pemasukan sparger

d. digunakan *flange standart tipe welding neck* pada
- Nozzle untuk pemasukan larutan H2SO4
- Nozzle untuk pengeluaran gas produk

**Perhitungan**

a. Nozzle untuk pemasukan H2SO4

- Rate Feed masuk = 21465.595 kg/jam = 4732
- Densitas = 97.000 $lb/ft^3$
- viskositas cairan = 0.0019 lb/ft.jam
- Q (Rate Volumetrik) $= \frac{47323.0504}{97.0000} = 487.8665$

$= 0.1355$ $ft^3/s$

Dari Peter & Timerhause didapatkan di optimum:

ID Optimal $= 3{,}9 \cdot Q^{0,45} \cdot P^{0,13}$

$= 3.9 \times 0.4068 \times 1.81251$

$= 2.8757$ in $\approx$ 2 in

$= 0.2396$ ft

(dari Kern, hal 844 maka dipilih pipa dengan ukuran 2 in)

| | | | | | |
|---|---|---|---|---|---|
| Ukuran pipa | = | 2.0000 | in | = | 0.1667 ft |
| OD | = | 2.3800 | in | = | 0.1983 ft |
| ID | = | 2.0670 | in | = | 0.1723 ft |
| a | = | 3.3950 | $in^2$ | = | 0.0236 $ft^2$ |

Pengecekan bilangan Reynold

$$Nre = \frac{G \times ID}{\mu \times a'}$$

$$= \frac{487.8665 \times 0.1723}{0.0019 \times 0.024}$$

$= 1875984.9066$ (Aliran Turbulen)

Spesifikasi nozzle standar (Brownel and Young, 1959, App. F item 1 dan 2, hal 349

- Size = 2
- OD of pipe = 2 3/8.
- Flange Nozzle thickness (n) = 0,218
- Diameter of hole in reinforcing plate (DR) = 2 1/2.
- Length of side of reinforcing plate, L = 10
- Width of reinforcing plate, W = 12 5/8
- Distance, shell to flange face, outside, J = 6
- Distance, shell to flange face, inside, K = 6
- Distance from Bottom of tank to center of nozzle
  * Regular, Type H = 6
  * Low, Type C = 3

b. Nozzle untuk feed gas

- Rate Feed gas masuk = 9541.9954 kg/jam = 2103
- Densitas = 97.0000 $lb/ft^3$
- Q (Rate Volumetrik) $= \frac{21036.2829}{97.0000} = 216.8689$

$= 0.0602 \quad ft^3/s$

Dari Peter & Timerhause didapatkan di optimum:

ID Optimal $= 3{,}9 \cdot Q^{0{,}45} \cdot P^{0{,}13}$

$= 3.9 \times 0.282457 \times 1.81251$

$= 1.9966$ in $\approx 2$ in

$= 0.1664$ ft

dari Kern, hal 844 maka dipilih pipa dengan ukuran 2 in:

| | | | | | |
|---|---|---|---|---|---|
| Ukuran pipa | = | 2.0000 | in | = | 0.1667 ft |
| OD | = | 2.3800 | in | = | 0.1983 ft |
| ID | = | 2.0670 | in | = | 0.1723 ft |
| A | = | 3.3950 | $in^2$ | = | 0.0236 $ft^2$ |

Spesifikasi nozzle standar (Brownel and Young, 1959, App. F item 1 dan 2, hal 349

- Size = 2
- OD of pipe = 2 3/8.
- Flange Nozzle thickness (n) = 0,218
- Diameter of hole in reinforcing plate (DR) = 2 1/2.
- Length of side of reinforcing plate, L = 10
- Width of reinforcing plate, W = 12 5/8
- Distance, shell to flange face, outside, J = 6
- Distance, shell to flange face, inside, K = 6
- Distance from Bottom of tank to center of nozzle
  * Regular, Type H = 6
  * Low, Type C = 3

c. Nozzle untuk Manhole

Lubang manhole dibuat berdasarkan standar yang ada yaitu : 20 inch

(Brownell & Young hal.51, Fig. 3.15)

Berdasarkan fig. 12.2 Brownell & Young hal.221, didapatkan dimensi pipa :

- Ukuran pipa nominal (NPS) = 20 in
- Diameter luar pipa (A) = 27.5 in
- Ketebalan flange minimum (T) = 1.69 in
- Diameter bagian lubang menonjol ( R ) = 23 in
- Diameter lubang pada titik pengelasan (K) = 20 in
- Diameter hubungan pada alas (E) = 22 in
- Panjang julikan (L) = 5.69 in
- Diameter dalam flange (B) = 19.3 in
- Jumlah lubang baut = 20 buah
- Diameter = 1.13 in

d. Nozzle untuk air pendingin inlet

Lubang untuk pemasukan dan pengeluaran steam dan kondensat dianggap sama dengan tebal jaket, yaitu = 3/16. sehingga berdasarkan fig. 12. Brownell and Young halaman 221, diperoleh dimensi pipa:

- Ukuran pipa nominal (NPS) = 1/2 in
- Diameter luar pipa (A) = 3 1/2 in
- Ketebalan flange minimum (T) = 7/16 in
- Diameter bagian lubang menonjol ( R ) = 1 3/8 in
- Diameter lubang pada titik pengelasan (K) = 0.84 in
- Diameter hubungan pada alas (E) = 1 3/16 in
- Panjang julikan (L) = 1 7/8 in
- Diameter dalam flange (B) = 0.62 in
- Jumlah lubang baut = 4 buah
- Diameter Baut = 1/2 in
- Ukuran Baut = 2 5/8 in

e. Nozzle Pengeluaran Produk Liquid

- Rate produk cair keluar = 2098.392374 kg/jam = 4626.115
- Densitas = 106.4029 $lb/ft^3$
- Suhu = 260.6000 °F
- P = 14.696 psia
- viskositas cairan = 0.94364 lb/ft.jam
- Q (Rate Volumetrik) = $\frac{4626.1158}{106.4029}$ = 43.4773 $ft^3$

= 0.0121 $ft^3/s$

Dari Peter & Timerhause didapatkan di optimum:

ID Optimal = $3{,}9 \cdot Q^{0{,}45} \cdot \rho^{0{,}13}$

= 3.9 x 0.13705 x 1.83444
= 0.9805 in
= 0.0817 ft

dari Kern, hal 844 maka dipilih pipa dengan ukuran 1 1/4 in sch 40:

| | | | | | | |
|---|---|---|---|---|---|---|
| Ukuran pipa | = | 1.2500 | in | = | 0.1042 | ft |
| OD | = | 1.6600 | in | = | 0.1383 | ft |
| ID | = | 1.3800 | in | = | 0.1150 | ft |
| a' | = | 1.5000 | $in^2$ | = | 0.0104 | $ft^2$ |

Pengecekan bilangan Reynold

$$Nre = \frac{G \times ID}{\mu \times a'}$$

$$= \frac{4626.1158 \times 0.1150}{0.9436 \times 0.010}$$

= 54122.9187 (Aliran Turbulen)

Spesifikasi nozzle standar (Brownel and Young, 1959, App. F item 1 dan 2, hal 349

- Size = 1
- OD of pipe = 1 4/7
- Flange Nozzle thickness (n) = 10
- Diameter of hole in reinforcing plate (DR) = 12 5/8
- Length of side of reinforcing plate, L = 6
- Width of reinforcing plate, W = 6
- Distance, shell to flange face, outside, J = 5
- Distance, shell to flange face, inside, K = 3
- Distance from Bottom of tank to center of nozzle
  * Regular, Type H = 5
  * Low, Type C = 4

f. Nozzle untuk keluaran air pendingin

Lubang untuk pemasukan dan pengeluaran air pendingin dan kondensat dianggap sama dengan tebal jaket, yaitu = 3/16. sehingga berdasarkan fig. 12. Brownell and Young halaman 221, diperoleh dimensi pipa:

- Ukuran pipa nominal (NPS) = 1/2 in
- Diameter luar pipa (A) = 3 1/2 in
- Ketebalan flange minimum (T) = 0.44 in
- Diameter bagian lubang menonjol ( R ) = 1 3/8 in
- Diameter lubang pada titik pengelasan (K) = 0.84 in
- Diameter hubungan pada alas (E) = 1 1/5 in
- Panjang julikan (L) = 1 7/8 in
- Diameter dalam flange (B) = 0.62 in
- Jumlah lubang baut = 4 buah
- Diameter = 5/8 in

g. Nozzle Pengeluaran Produk Gas

- Rate produk gas keluar = 17180.33294 kg/jam = 37875.76
- Densitas = 42.2784 $lb/ft^3$
- Suhu = 260.6000 °F
- P = 14.696 psia
- viskositas gas = 0.30198 lb/ft.jam
- Q (Rate Volumetrik) = $\frac{37875.7620}{42.2784}$ = 895.86 $ft^3$

= 0.2489 $ft^3/s$

Dari Peter & Timerhause didapatkan di optimum:

ID Optimal = $3{,}9 \cdot Q^{0{,}45} \cdot \rho^{0{,}13}$

= 3.9 x 0.5348 x 1.62703

= 3.3934 in ≈ 4 in

= 0.2828 ft

dari Kern, hal 844 maka dipilih pipa dengan ukuran 16in sch 40:

| | | | | | | |
|---|---|---|---|---|---|---|
| Ukuran pipa | = | 16 | in | = | 1.3333 | ft |
| OD | = | 16 | in | = | 1.3333 | ft |
| ID | = | 15.2500 | in | = | 1.2708 | ft |
| a' | = | 183 | $in^2$ | = | 1.2708 | $ft^2$ |

Pengecekan bilangan Reynold

Nre = $\frac{G \times ID}{\mu \times a'}$

= $\frac{37875.7620 \times 1.2708}{0.3020 \times 1.271}$

= 125423.8592 (Aliran Turbulen)

Spesifikasi nozzle standar (Brownel and Young, 1959, App. F item 1 dan 2, hal 349

- Size = 16
- OD of pipe = 16
- Flange Nozzle thickness (n) = 1/2
- Diameter of hole in reinforcing plate (DR) = 16 1/8
- Length of side of reinforcing plate, L = 35
- Width of reinforcing plate, W = 42 7/8
- Distance, shell to flange face, outside, J = 10
- Distance, shell to flange face, inside, K = 8
- Distance from Bottom of tank to center of nozzle
  - * Regular, Type H = 20
  - * Low, Type C = 17 1/2

Dari Brownel & Young tabel 12.2 halaman 221 diperoleh dimensi flange untuk semua nozzle, dipilih flange standart type welding neck dengan dimensi :

- Nozzle A = Nozzle pemasukan H2SO4

- Nozzle B = Nozzle pemasukan Udara
- Nozzle C = Nozzle pemasukan air pendingin
- Nozzle D = Nozzle pengeluaran produk liquid
- Nozzle E = Nozzle untuk manhole
- Nozzle F = Nozzle pengeluaran air pendingin
- Nozzle G = Nozzle pengeluaran produk gas
- NPS = Ukuran pipa nominal, in
- A = Diameter luar flange, in
- T = Ketebalan minimum flange, in
- R = Diameter luar bagian yang menonjol, in
- E = Diameter hubungana atas, in
- K = Diameter hubungan pada titik pengelasan, in
- L = Panjang julakan, in
- B = Diameter dalam flange, in

| Nozzle | NPS | A | T | R | E | K | L |
|---|---|---|---|---|---|---|---|
| A | 2 | 7 1/2 | 15/16 | 5 | 4 1/4 | 3.5 | 2 3/4 |
| B | 2 | 9 | 15/16. | 6 3/16. | 5 5/16. | 4.50 | 3 |
| C | 20 | 3 1/2 | 7/16` | 1 3/8 | 1.3/16 | 0.84 | 1 7/8 |
| D | 1/2 | 7 1/2 | 15/16 | 5 | 4 1/4 | 3.5 | 2 3/4 |
| E | 1 | 27.5 | 1 11/16 | 23 | 22 | 20 | 5 11/16 |
| F | 1/2 | 3 1/2 | 7/16` | 1 3/8 | 1.3/16 | 0.84 | 1 7/8 |
| G | 16 | 25 | 1 9/16. | 21 | 19 7/8. | 18 | 5 1/2 |

**6.6 Sambungan Tutup (Head) dengan Dinding Reaktor**

Bagian tutup reaktor dan bagian shell reaktor dihubungkan secara flange dan bolting untuk mempermudah perbaikan dan perawatan reaktor.

**1. Gasket**

Dari Brownell & Young, fig. 12.11 hal. 228, didapatkan :

Bahan konstruksi : Asbestos Filled Stainless steel
Gasket factor (m) : 3.75
min design seating stress (y) : 9000 psia

**2. Bolting**

Dari Brownell & Young, App. D-4 hal. 344, didapatkan :

Bahan konstruksi : High Alloy Steel SA 193 Grade B8c Type 34
Tensile strength minimum : 75000 psia
Allowable stress (f) : 15000

**3. Flange**

Dari Brownell & Young, App. D-4 hal. 342, didapatkan :

Bahan komstruksi : High Alloy Steel SA 240 Grade M Type 316
Tensile strength minimum : 75000 psia
Allowable stress (f) : 18750

**a. Penentuan lebar gasket**

Penentuan lebar gasket dengan mengunakan pers. 12.2, hal. 226, Brownell

& Young didapatkan:

$$\frac{do}{di} = \sqrt{\frac{y - p.m}{y - p\,(m+1)}}$$

Dimana:
do = diameter luar gasket, in
di = diameter dalam gasket, in
P = internal pressure = 14.70 psia
m = gasket faktor = 3.75 in (fig. 12.11, Brownell & Young)
y = min. Design seating stress = 9000 psi (fig. 12.11, Brownell & Y
maka:

$$\frac{do}{di} = \sqrt{\frac{9000 - .14.70 \times 3{,}75}{9000 - 14.70(3{,}75+1)}}$$

$\frac{do}{di}$ = 1.00082248 ft

di gasket = do shell = 1.1146 ft
DO = 1.0008 x 1.1146
= 1.1155 ft
= 13.386 in
Lebar gasket min = $\frac{do - di}{2}$
= $\frac{0.011}{2}$
= 0.0055 in
Diambil Gasket (n) = 0.0055 in

D rata Gasket (G) = do + n
= 13.3750 + 0.0055
= 13.3805 in
= 1.1150 ft

**b. Perhitungan jumlah dan ukuran baut (Bolting)**

- Perhitungan beban baut
- Dari Brownell & Young, persamaan 12.88 hal. 240 :
  Beban gasket supaya tidak bocor (Hy)
  $Wm_2$ = Hy = $\pi$.b.G.y
- Dari Brownell & Young, persamaan 12.12 hal. 229 :
  Lebar setting gasket bawah:
  bo = n/2
  = 0.0028 in
- Sehingga Hy

$Wm_2$ = Hy = π.b.G.y
= 3.14 x 0.0028 x 13.3805 x 90
= 1039.932 lb

- Dari Brownell & Young, persamaan 12.90 hal. 240 :
  Beban baut agar tidak bocor (Hp)
  Hp = 2.π.b.G.m.p
  = 6.28 x 0.0028 x 13.3805 x 3.75 x
  = 12.7356163 lb
- Dari Brownell & Young, persamaan 12.89 hal. 240 :
  Beban karena tekanan dalam (H)
  H = π/4.G².p
  = 2065.4303 lb
- Dari Brownell & Young, persamaan 12.91 hal. 240 :
  Total berat beban pada kondisi operasi (Wml)
  $W_{ml}$ = H + Hp
  = 2065.4303 + 12.73561628
  = 2078.1660 lb
  Karena Wml > $Wm_2$, maka yang mengontrol adalah Wml.

- Perhitungan luas minimum bolting area
  Dari Brownell & Young, persamaan 12.93 hal. 240 :

$$A_{ml} = \frac{Wml}{fb}$$

$$= \frac{2078.17}{15000}$$

= 0.1385 $in^2$ = 0.0010 $ft^2$

- Perhitungan Bolting Optimum
  Dari Brownell & Young, tabel 10.4 hal. 188 :
  Ukuran Baut = 1/2 in
  Root Area = 0.126 in

$$\text{Jumlah Bolting minimum} = \frac{Aml}{\text{Root area}}$$

$$= \frac{0.480}{0.126}$$

= 3.808442 ≈ 4

- Dari Brownell & tabel 10.4 hal. 188 :
  Bolt spacing = 1 1/4 in
  Minimum radial distance (R) = 13/16 in
  Edge distance (E) = 3/8 in

- Bolting circle diameter (C) : g = ts = $\frac{3}{16}$
  C = di shell + 2 (1,415 . g+ R)

= 13.3750 + 2 x (1,415 x 3/16) + 13/16
= 15 26/49

- Diameter luar flange
  OD = C + 2 E
  = 16.2806 in
- Check lebar gasket

  Ab actual = Jumlah Bolt x Root area
  Ab actual = 4 x 0.126
  Ab actual = 0.504 $in^2$

- Lebar gasket minimum

$$L = \text{Ab actual} \times \frac{f}{2\pi.G.y}$$

  L = 0.504 x 0.0198
  L = 0.01 in

- Karna L< n ( 0.000070 < 0.005500 ) maka perhitungan boltin memenuhi
- Perhitungan Moment
  Dari Brownell & Young, persamaan 12.94 hal. 242, untuk keadaan bolting up (tanpa tekanan uap dalam) :

$$W = \frac{Am + Ab}{2} \times f$$

  = 4819.082979 lb (Brownell & Young, pers. 12.94 hal. 24

- Jarak radial dari beban gasket yang bereaksi terhadap bolt circle
  $h_G$ = (C-G)/2
  = 1.0751 in
- Moment flange (Ma) :
  Dari Brownell & Young, halaman 243
  Ma = W x $h_G$
  Ma = 5180.814546 lb.in
  Dari Brownell & Young, pers. 12.95 hal. 243 :
  Dalam kondisi operasi :
  W = W ml = 2078.1660 lb

- Hidrastic and force pada daerah dalam flange (HD)
  Dari Brownell & Young, pers. 12.96 hal. 243 :
  B = do shell reactor = 14 in

p = Tekanan Operasi = 14.70 psia

HD = 0,785 . B² .p
= 0.785 x 196 x 14.70
= 2261.1112 lb

- Jarak radial bolt circle pada aksi (hD)

Dari Brownell & Young, pers. 12.100 hal. 243 :

hD = (C-B)/2
= $\frac{15\ 26/49 - 14}{2}$
= 0.7653 in

- Moment MD

Dari Brownell & Young, pers. 12.96 hal. 242

$M_D$ = hD x HD
= 0.7653 x 2261
= 1730.456645 lb.in

- Perbedaan antara beban baut flange dengan gaya hidrostatik total ($H_G$)

$H_G$ = W - H
= 2078.1660 - 2065.4303
= 12.7356 lb

- Moment MG

Dari Brownell & Young, pers. 12.98 hal. 242 :

$M_G$ = $H_G$ x $h_G$
= 13.6915812 lb.in

Dari Brownell & Young, pers. 12.97 hal. 242 :

$H_T$ = H - $H_D$
= 195.6808 lb

Dari Brownell & Young, pers. 12.102 hal. 244 :

$h_T$ = $\frac{h_G + h_D}{2}$
= 0.9202 in

- Moment $M_T$

Dari Brownell & Young, pers. 12.97 hal. 242 :

$M_T$ = $H_T$ x $h_T$
= 180.063039 lb.in

- Moment total pada keadaan operasi (Mo)

Mo = $M_D$ + $M_G$ + $M_T$
= 1924.2113 lb.in

- Dikarenakan Ma > Mo maka Mmax adalah Ma = 5180

**c. Perhitungan tebal Flange**

Dari Brownell & Young, pers. 12.85 hal. 239 :

$$f_T = \frac{Y.\,Mo}{t^2 . B}$$

$$t = \sqrt{\frac{Y \times Mo}{f_T \times B}}$$

$$k = A/B$$

Dimana:

A = Diameter luar flange = 16.2806 in

B = Diameter dalam flange = 15.5306 in

$f_T$ = Allowable Stress Flange = 18750

maka, $k = \frac{A}{B} = \frac{16.2806}{15.5306}$

$= 1.0483$

Dari Brownell & Young, fig. 12.22 hal 238, didapatkan :

Y = 75

M = 5180.8145 lb.in

Sehingga tebal Flange

$$t = \sqrt{\frac{Y \times Mo}{f_T \times B}}$$

$$t = \sqrt{\frac{75 \times 5180.8145}{18750 \times 15.5306}}$$

t = 1.1551 in

**Kesimpulan Perancangan Reaktor:**

- **Flange**

| | | |
|---|---|---|
| Bahan konstruksi | : | High Alloy Stell SA 240 Grade M |
| Tensile strength minimum | : | 75000 psia |
| Allowable stress (f) | : | 15000 |
| Tebal flange | : | 1.1551 in |
| Diameter dalam (Di) | : | 15.5306 in |
| Diameter luar (Do) | : | 16.2806 in |
| Type flange | : | Ring flange Loss Type |

- **Bolting**

| | | |
|---|---|---|
| Bahan konstruksi | : | High Alloy Stell SA 193 Grade M |
| Tensile strength minimum | : | 75000 psia |
| Allowable stress (f) | : | 15000 |

| | | | | |
|---|---|---|---|---|
| Ukuran Baut | : | 1/2 | in | |
| Jumlah Baut | : | 4 | buah | |

- **Gasket**

| | | | |
|---|---|---|---|
| Bahan konstruksi | : | Asbestos Filled Stainless steel | |
| Gasket factor (m) | : | 3.75 | |
| min design seating stress (y) | : | 9000 | psia |
| Tebal Gasket (n) | : | 0.0055 | in |

## 6.7. Perhitungan Sistem Penyangga Reaktor

Sistem penyangga dirancang agar mampu untuk penyangga beban reaktor dan perlengkapannya.

- Berat shell reaktor
- Berat tutup atas standart dishead
- Berat tutup bawah reaktor
- Berat liquid dalam reaktor
- Berat pengaduk dan perlengkapannya
- Berat jaket pendingin
- Berat attachment

**Dasar Perhitungan :**

**a. Berat shell reaktor**

Rumus :

$$Ws = \pi/4 \, (do^2 - di^2) \, H \, . \, \rho$$

Dimana :

| | | | | | | |
|---|---|---|---|---|---|---|
| Ws | = | berat shell reaktor, lb | | | | |
| do | = | diameter luar shell | = | 14 | in | = |
| di | = | diameter dalam shell | = | 13.3750 | in | = |
| H | = | tinggi shell reaktor (Ls) | = | 72.7983 | in | |
| ρ | = | densitas dari bahan konstruksi | = | 489 | lb/ft | |

Berat shell reaktor

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Ws | = | $\pi/4 \, (do^2 - di^2) \, H \, . \, \rho$ | | | | | | |
| Ws | = | 0.79 | x | 0.1188 | x | 6.067 | x | 489 |
| Ws | = | 276.6878 | lb | | | | | |
| Ws | = | 125.4820 | kg | | | | | |

**b. Berat tutup atas standart dishead**

Rumus :

| | | | | | |
|---|---|---|---|---|---|
| Wd | = | A . t . ρ | | | |
| A | = | 6,28 . L . h | | | |

Dimana :

| | | | | | | |
|---|---|---|---|---|---|---|
| Wd | = | Berat tutup atas reaktor, lb | | | | |
| A | = | Luas tutup atas standart dishead, $ft^2$ | | | | |
| t | = | Tebal tutup atas (tha) | = | 1/16. | in | = |
| ρ | = | ρ bahan konstruksi | = | 489 | $lb/ft^3$ | |

L = Crown radius (r) = 14 in =
h = Tinggi tutup atas reaktor (ha) = 27.1245 in =

Luas Tutup atas

A = 6,28 . L . h
= 6.28 x 1.167 x 2.2604
= 16.561 $ft^2$
= 2384.7860 $in^2$

Sehingga berat tutup atas,

Wd = A . t . ρ
= 16.5610 x 0.0156 x 489
= 126.5365 lb
= 57.3862 kg

**c. Berat tutup bawah standart dishead**

Rumus :

Wd = A . t . ρ
A = 6,28 . L . h

Dimana :

Wd = Berat tutup bawah reaktor, lb
A = Luas tutup bawah standart dishead, $ft^2$
t = Tebal tutup bawah (thb) = 1/16. in =
ρ = ρ bahan konstruksi = 489 $lb/ft^3$
L = Diameter dalam silinder (di) = 13.3750 in =
h = Tinggi tutup bawah reaktor (ha) = 27.1245 in =

Luas Tutup atas

A = 6,28 . L . h
= 6.28 x 1.115 x 2.2604
= 15.8217 $ft^2$
= 2278.3224 $in^2$

Sehingga berat tutup atas,

Wd = A . t . ρ
= 15.8217 x 0.0156 x 489
= 120.8875 lb
= 54.8243 kg

**d. Berat Liquid dalam reaktor**

Rumus :

$W_l$ = m . t

Dimana :

- m = Berat larutan dalam reaktor = 21465.5948
- t = Waktu tinggal liquid dalam reaktor = 0.0022

$W_l$ = m . t
= 21465.5948 x 0.0022
= 46.3094116 lb

= 21.0020 kg

**e. Berat Jaket Pendingin**

Rumus:

$W_{Jaket}$ = $\pi/4\ (do_J^2 - di_J^2)\ T_j \cdot \rho$

Dimana

- $W_{Jaket}$ = Berat Jaket (lb)
- $do_j$ = Diameter luar jaket = 13.7500 in =
- $di_j$ = Diameter dalam jaket = 13.6250 in =
- $T_j$ = Tinggi jaket = 176.6201 in =
- $\rho$ = $\rho$ bahan konstruksi = 489.0000 $lb/ft^3$

$W_{Jaket}$ = $\pi/4\ (do_J^2 - di_J^2)\ T_j \cdot \rho$

= 0.79 x 0.024 x 14.7183 x 489

= 134.257672 lb

= 60.8878 kg

Berat Air Pending

$W_{Air}$ = V Air x $\rho$ Air = 191.0232 x 62.1304

= 11868.35564 lb

= 5382.4742 kg

Jadi berat keseluruhan jaket pendingin adalah

$W_{jaket + Air}$ = 60.8878 + 5382.4742

= 5443.3620 kg

**f. Berat *Attachment***

Berat attachment merupakan berat dari seluruh perlengkapan seperti nozzle, dan sebagainya.

Dari Brownell & Young, hal. 157 :

$W_A$ = 18% dari $W_S$

$W_A$ = 18% x 125.4820

$W_A$ = 22.5868 kg

**Berat Total Reaktor**

| No. | Bagian | Berat (Kg) |
|---|---|---|
| 1 | $W_{shell}$ | 125.4820 |
| 2 | $W_{Tutup\ atas}$ | 57.3862 |
| 3 | $W_{Tutup\ bawah}$ | 54.8243 |
| 4 | $W_{Liquid}$ | 21.0020 |
| 5 | $W_{Jaket+steam}$ | 5443.3620 |
| 6 | $W_{Attachment}$ | 22.5868 |
| **$W_{Total}$** | | **5724.6433** |

Dengan faktor keamanan adalah 10%, maka berat total berat reaktor

Berat Total Reaktor = 110% x $W_{Total}$

= 1.10 x 5724.6433

= 6297.107596 Kg

## 6.8 Perhitungan Kolom Penyangga Reaktor (Leg)

Dasar Perencanaan

- Menggunakan 4 buah kolom penyangga (kaki penahan)
- Jenis kolom yang digunakan : I beam

Dasar Perhitungan

a. Beban tiap kolom

Dari Brownell & Young, pers. 10.76 hal. 197 :

$$P = \frac{4.\ P_W\ (H-L) + \Sigma W}{n.\ D_{bc} + n}$$

Dimana :

P = Beban tiap kolom, lb
Pw = Total beban permukaan karena angin, lb
H = Tinggi vessel dari pondasi, ft
L = Tarak antara vessel dengan dasar pondasi, ft
Dbc = Diameter anchor bolt circle, ft
n = Jumlah support = 4
SW = Berat total, lb
P = Beban kompresi total maksimum untuk tiap leg, lb

Reaktor diletakkan di dalam ruangan, sehingga tidak dipengaruhi adanya tekanan angin (beban tekanan angin tidak dikontrol).

Maka berlaku rumus :

$P_W = 0$

maka,

$$P = \frac{\Sigma W}{n}$$

$$= \frac{6297.1076}{4}$$

= 1574.2769 kg

Direncanakan :

- Jarak kolom penyangga dari tanah (L) = 5 ft
- Beban tiap kolom = 1574.2769 kg = 3471.280
- Tinggi reaktor (H) = 208.4208 in = 17.3684
- Panjang penyangga (L) = 0,5 . (H+L)
  = 0.5 x 17.3684 + 5
  = 11.1842 ft
  = 3.4089 m

b. Trial ukuran I beam

Untuk pemilihan beam dicoba menggunakan ukuran 5 in 6x3 3/8 dengan berat 17.25 lb dari Brownell & Young Hal. 355

Dari Brownell & Young, App. G-3 hal. 355, didapatkan :

b = 5 in

h = 12 in
Ay = 9.26 $in^2$
r = 4.83 in
maka :

$$\frac{L}{r} = \frac{208.4208}{4.8300}$$

= 43.1513 in
= 3.5959 ft
Untuk L/r kurang dari 120 in maka,
fc = 15000 psi

(Brownell & Young Hal. 201)

fc aman = fc, maka:

$$A = \frac{P}{fc\ aman}$$

$$A = \frac{3471.2806}{15000}$$

A = 2.3142 $in^2$ < 9.26 $in^2$ (Memadai)

Karena A < A yang tersedia, berarti trial I beam sudah memadai.
Kesimpulan perancangan penyangga (leg) :

- Ukuran I beam = 12 x 5
- Berat = 5.000 lb
- Jumlah penyangga = 4

## 6.9. Perencanaan Base Plate

Dibuat base plate dengan toleransi panjang 5% dan toleransi lebar 20%
(Hesse, Hal 163)

Bahan Base Plate = Concrate beton, maka :
fbp = 600 $lb/in^2$ (Hesse, Tabel 7.7 hal. 162)

### a. Luas Base Plate

$$A_{Base\ Plate} = \frac{P}{fbp}$$

$$= \frac{3471.2806}{600}\ \frac{lb}{lb/in^2}$$

= 5.7855 $in^2$

### b. Panjang dan lebar base plate

$A_{Base\ Plate}$ = l x p
Dimana :

- l = Lebar Base Plate = 2n + 0.8 b
- p = Panjang Base Plate = 2m + 0.95 h

Dengan I Beam 10 in maka:

- b = 5 in
- h = 12 in

Dengan asumsi m=n maka:

$A_{Base\ Plate}$ = l x p

5.7855 = (2n + 0.8 b) x (2m + 0.95 h

5.7855 = (2m + 0.8 5 ) x (2m + 0

5.7855 = (2m + 4 ) x (2m + 11.4 )

5.7855 = 4 $m^2$ + 30.8000 m + 45.600

0 = 4 $m^2$ + 30.8000 m - -39.8145

Dengan menggunakan rumus persamaan kuadrat, didapatkan

$$m_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$m_1$ = 1.64345 in

$m_2$ = 6.05655 in

Didapatkan nilai m=n adalah 1.6434 in maka,

l = 2n + 0.8 b

= 3.2869 + 4.0000

= 7.2869 in ≈ 8 in

p = 2m + 0.95 h

= 3.2869 + 11.4000

= 14.6869 in ≈ 15 in

jadi Luas Base Plate = l x p

= 8 x 15

= 120.0000 in

**c. Peninjauan terhadap bearing capacity (f)**

Beban yang harus ditahan

$$fc = \frac{P}{A}$$

$$= \frac{3471.2806}{}$$

$$= \frac{120.0000}{28.9273} \text{ psi} \quad \text{(memenuhi karena < 600 lb/in}^2\text{)}$$

**d. Menghitung nilai m dan n baru**

- $l = 2n + 0.8\,b$
  $8 = 2n + 4$
  $n = 2.0000$

- $p = 2m + 0.95\,h$
  $15 = 2m + 11.4000$
  $m = 1.8000 \text{ in}$

nilai yang terbesar diambil untuk menghitung tebal base plate (tbp)

**e. Tebal base plate**

Dari Hesse, pers. 7-12 hal. 163 :

$$tbp = \sqrt{0{,}00015 \times fbaru}$$
$$= \sqrt{0{,}00015 \times 28.927 \times 1.8000}$$
$$= 0.1186 \text{ in}$$

**f. Ukuran baut**

Menentukan ukuran baut

Jumlah Baut = 4 buah

$$P_{baut} = \frac{P}{n}$$
$$= \frac{3471.2806}{4}$$
$$= 867.8201 \text{ lb}$$

Menentukan luas baut (A)

ft = Stress maksimal tiap baut = 12000 psi

$$A_{baut} = \frac{P_{baut}}{ft}$$
$$= \frac{867.8201}{12000}$$
$$= 0.0723 \text{ in}^2$$

Menentukan db baut

$A_{baut} = \pi/4 \times db^2$

$0.0723 = 0.79 \times db^2$

$db^2$ = 0.09213
db = 0.30352 in
= 1/3 in

Dari tabel 10.4 hal. 188 Brownell & Young, didapatkan baut dengan ukuran 1/2 in adalah :

- Ukuran = 1/2 in
- Root area = 0.126 $in^2$
- Bolt spacing = 1 1/4 in
- Minimum radial distance = 1 3/16 in
- Edge distance = 5/8 in
- Nut dimension = 7/8 in
- Maximum fillet radius = 1/4 in

## 6.10. Perencanaan Lug dan Gusset

Direncanakan menggunakan :

- 2 Plate horizontal (lug)
- 2 Plate vertikal (gusset)

Dari fig. 10.6 hal. 192 Brownell & Young

**a. Lebar Lug**

didapatkan nilai A = ukuran baut + 9 in

Lebar Lug = A = 0.3035 + 9 in

A = 9.3035 in

Jarak antar Guset = b = ukuran baut + 8 in

b = 0.3035 + 8 in

b = 8.3035 in

**b. Lebar Guset**

- lebar guset = l = 2 x (lebar base plate - 0,5 x ukuran baut)

  = 2 x ( 8 - 0.5 x 0.3035

  = 15.6965 in

- Lebar lug atas (a) = 0,5 x (1+ukuran baut)

  = 0.5 x ( 1 + 1/2 )

  = 22464.50 in

- Perbandingan tebal base plate

$$= \frac{b}{l}$$

$$= \frac{8.3035}{15.6965}$$

$$= 0.52901$$

didapat nilai b/l = 1 digunakan tabel 10.6 Hal. 192 Brownell & Young)

- $\Upsilon_I$ = 0.5650
- e = 0.5 x nut dimension

  = 0.5 x 7/8

= 0.4375

**c. Tebal Plate Horizontal (Lug)**

Menentukan maksimum bending moment sepanjang sumbu radial
Pers. 10.38 Hal 192 Brownell & Young

$$M_Y = \frac{P}{4\pi}\left[(1+\mu)\times \ln\frac{2L}{\pi . e}\right.$$

Dimana :

- P = Beban tiap baut = 867.8201 lb
- μ = Posson's ratio = 0.33
- L = Panjang horizontal plate bawah = 15.6965 in
- e = Nut dimension = 0.4375
- $\Upsilon_I$ = 0.5650

Jadi,

$$M_Y = \frac{P}{4\pi}\left[(1+\mu)\times \ln\frac{2L}{\pi . e}\right.$$

$M_Y$ = 69.094 x( 1.33 x ln 22.8520 + 0.4350
= 317.59884 lb

$M_Y$ disubstitusi ke pers. 10.41 Hal. 193 Brownell & Young, sehingga diperoleh:

$$thp = \sqrt{\frac{6 \times M_Y}{f}}$$

thp = 0.3985 in

Maka digunakan plate dengan tebal = 0.3985 in

**d. Tebal Plate Vertikal (Gusset)**

Dari fig. 10.6 hal. 191 pers. 10.47 hal. 194 diperoleh :

tebal gusset minimal = 0.375 x thp
= 0.375 x 0.3985
= 0.1494 in

**e. Tinggi Gusset**

Tinggi gusset (Hg) = A + Ukuran baut
= 9.3035 + 1/2
= 9.8035 in

**f. Tinggi Lug**

Tinggi Lug = Hg + 2 thp
= 9.8035 + 2 0.3985
= 10.6005 in

Kesimpulan dimensi lug dan gusset :

Lug
- Lebar = 9.3035 in
- Tebal = 0.3985 in
- Tinggi = 10.6005 in

Gusset
- Lebar = 15.6965 in
- Tebal = 0.14944 in
- Tinggi = 9.8035 in

## 6.11. Perencanaan Pondasi

Dasar Perencanaan:

Beban total yang harus ditahan pondasi
- Berat reaktor total
- Berat kolom penyangga
- Berat base plate

Ditentukan:
- Masing-masing penyangga diberi pondasi
- Spesifik untuk semua penyangga sama

**a. Berat Total Reaktor**

W = 6,297.1076 kg = 13,885.1222 lb

**b. Beban yang harus ditanggung tiap kolom**

Rumus:

Wbp = P x l x tbp x ρ
= 1.25 x 0.6667 x 0.0099 x
= 4.0264 lb

**c. Beban tiap penyangga**

F = Faktor korosi = 3.4

Wp = L x A x F x ρ
= 11.1842 x 0.0161 x 3.4 x 489
= 298.8331 lb

**d. Beban total**

$W_{Total}$ = W + Wbp + Wp
= 13,885.1222 + 4.03 + 298.8331
= 14187.9817 lb

Dianggap hanya ada gaya vertikal dan berat kolom itu sendiri bekerja pada pondasi, maka diambil :

- Luas atas = 15 x 15 in
- Luas bawah = 40 x 40 in
- Tinggi = 20 in
- Luas permukaan tanah rata-rata:

A = 40 x 40

= 1600 $in^2$

Volume Pondasi

V = A x tinggi

= 2.3142 x 20

= 46.2837 $in^3$

= 0.026752 $ft^3$

ρ semen = 144 $lb/ft^3$

maka, berat pondasi :

W = V x ρ

= 0.3214 x 144

= 46.2837 lb

= 20.9904 kg

Tekanan tanah:

Pondasi didirikan diatas semen sand dan gravel, dengan:

- Save bearing minimum = 5 $ton/ft^2$
- Save bearing maksimum = 10 $ton/ft^2$

Kemampuan tekanan tanah sebesar:

$$P = 5\ ton/ft^2 \times \frac{2204{,}623\ lb \times 1\ ft}{1\ ft \times 144\ in^2}$$

$$P = 76.5494\ lb/in^2$$

Tekanan pada tanah :

$$P = \frac{W_{Total} + W_{Pondasi}}{A_{Luas\ bawah\ Pondasi}}$$

$$P = \frac{14187.982 + 46.2837}{1600}$$

$$P = 8.8964\ lb/in^2$$

Tekan tanah < Kemampuan tekanan tanah

8.8964 $lb/in^2$ < 76.5494 $lb/in^2$

Karena tekanan yang diberikan tanah lebih kecil daripada kemampuan tanah menahan pondasi, maka pondasi dengan ukuran (15 x 15) in² untuk luas atas dan (40 x 40) in² untuk luas bawah dengan tinggi pondasi 20 in dapat digunakan.

**Dimensi Peralatan :**

**1. Dimensi Tangki Reaktor**

- Bahan Konstruksi = High Alloy Stell SA 240 Grade M type 316
- Diameter Luar (do) = 13.2649 in
- Diameter Dalam (di) = 13.3750 in
- Tinggi Silinder (Ls) = 72.7983 in
- Tebal tutup atas (tha) = 1/16. in
- Tinggi tutup atas (ha) = 27.1245 in
- Tebal tutup bawah (thb) = 1/16. in
- Tinggi tutup bawah (hb) = 27.1245 in
- Tinggi reaktor (H) = 208.4208 in

**2. Jaket Pendingin**

- Bahan Konstruksi = High Alloy Stell SA 240 Grade M
- Diameter luar (do) = 13.7500 in
- Diameter dalam (di) = 13.6250 in
- Tinggi Jaket (L) = 176.6201 in
- Tebal Jaket (ts) = `1/16 in
- Tebal Jaket tutup bawah (thb) = `1/16 in
- Tinggi jaket tutup bawah (hb) = 2.2604 in

**3. Sparger Udara**

- Luas lubang sparger = 0.7352 $in^2$
- Rate volumetric gas = 3.6145 $ft^3$/menit
- Jarak antar lubang ($P_T$) = 0.50000 in
- Luas satu segitiga = 0.5771 $in^2$
- Jumlah lubang = 25 buah

**4. Shower Liquid H2SO4**

- Luas lubang shower = 64.0356 $in^2$
- Rate volumetric = 16.0427 $ft^3$/menit
- Jarak antar lubang ($P_T$) = 0.5000 in
- Luas satu segitiga = 0.1083 $in^2$
- Jumlah lubang = 25 buah

**5. Bagian Nozzle**

**a. Nozzle untuk pemasukan H2SO4**

- Type = Welding neck
- Size = 2 in
- OD of pipe = 2 3/8. in
- Flange Nozzle thickness (n) = 0,218 in
- Diameter of hole in reinforcing plate (DR) = 2 1/2. in
- Length of side of reinforcing plate, L = 10 in
- Width of reinforcing plate, W = 12 5/8 in
- Distance, shell to flange face, outside, J = 6 in
- Distance, shell to flange face, inside, K = 6 in
- Distance from Bottom of tank to center of nozzle

| | | | | | |
|---|---|---|---|---|---|
| | * Regular, Type H | = | 6 | in |
| | * Low, Type C | = | 3 | in |
| **b.** | **Nozzle untuk feed gas udara** | | | |
| | - Size | = | 2 | in |
| | - OD of pipe | = | 2 3/8. | in |
| | - Flange Nozzle thickness (n) | = | 0,218 | in |
| | - Diameter of hole in reinforcing plate (DR) | = | 2 1/2. | in |
| | - Length of side of reinforcing plate, L | = | 10 | in |
| | - Width of reinforcing plate, W | = | 12 5/8 | in |
| | - Distance, shell to flange face, outside, J | = | 6 | in |
| | - Distance, shell to flange face, inside, K | = | 6 | in |
| | - Distance from Bottom of tank to center of nozzle | | | |
| | * Regular, Type H | = | 6 | in |
| | * Low, Type C | = | 3 | in |
| **c.** | **Nozzle untuk manhole** | | | |
| | - Type | = | Welding neck | |
| | - Ukuran pipa nominal (NPS) | = | 20 | in |
| | - Diameter luar pipa (A) | = | 27.5 | in |
| | - Ketebalan flange minimum (T) | = | 1.69 | in |
| | - Diameter bagian lubang menonjol ( R ) | = | 23 | in |
| | - Diameter lubang pada titik pengelasan (K) | = | 20 | in |
| | - Diameter hubungan pada alas (E) | = | 22 | in |
| | - Panjang julikan (L) | = | 5.69 | in |
| | - Diameter dalam flange (B) | = | 19.3 | in |
| | - Jumlah lubang baut | = | 20 | bual |
| | - Diameter | = | 1.13 | in |
| **d.** | **Nozzle untuk air pendingin masuk** | | | |
| | - Ukuran pipa nominal (NPS) | = | 1/2 | in |
| | - Diameter luar pipa (A) | = | 3 1/2 | in |
| | - Ketebalan flange minimum (T) | = | `7/16 | in |
| | - Diameter bagian lubang menonjol ( R ) | = | 1 3/8 | in |
| | - Diameter lubang pada titik pengelasan (K) | = | 0.84 | in |
| | - Diameter hubungan pada alas (E) | = | 1 3/16 | in |
| | - Panjang julikan (L) | = | 1 7/8 | in |
| | - Diameter dalam flange (B) | = | 0.62 | in |
| | - Jumlah lubang baut | = | 4 | bual |
| | - Diameter Baut | = | `1/2 | in |
| | - Ukuran Baut | = | 2 5/8 | in |
| **e.** | **Nozzle Pengeluaran Produk Liquid** | | | |
| | - Size | = | 1 | in |
| | - OD of pipe | = | 1 4/7 | in |
| | - Flange Nozzle thickness (n) | = | 10 | in |
| | - Diameter of hole in reinforcing plate (DR) | = | 12 5/8 | in |
| | - Length of side of reinforcing plate, L | = | 6 | in |
| | - Width of reinforcing plate, W | = | 6 | in |

- Distance, shell to flange face, outside, J = 5 in
- Distance, shell to flange face, inside, K = 3 in
- Distance from Bottom of tank to center of nozzle
  * Regular, Type H = 5 in
  * Low, Type C = 4 in

**f. Nozzle untuk keluaran air pendingin**

- Ukuran pipa nominal (NPS) = 1/2 in
- Diameter luar pipa (A) = 3 1/2 in
- Ketebalan flange minimum (T) = 0.44 in
- Diameter bagian lubang menonjol ( R ) = 1 3/8 in
- Diameter lubang pada titik pengelasan (K) = 0.84 in
- Diameter hubungan pada alas (E) = 1 1/5 in
- Panjang julikan (L) = 1 7/8 in
- Diameter dalam flange (B) = 0.62 in
- Jumlah lubang baut = 4 buah
- Diameter = 5/8` in

**g. Nozzle Pengeluaran Produk Gas**

- Size = 16 in
- OD of pipe = 16 in
- Flange Nozzle thickness (n) = 1/2 in
- Diameter of hole in reinforcing plate (DR) = 16 1/8 in
- Length of side of reinforcing plate, L = 35 in
- Width of reinforcing plate, W = 42 7/8 in
- Distance, shell to flange face, outside, J = 10 in
- Distance, shell to flange face, inside, K = 8 in
- Distance from Bottom of tank to center of nozzle
  * Regular, Type H = 20 in
  * Low, Type C = 17 1/2 in

Dari Brownel & Young tabel 12.2 halaman 221 diperoleh dimensi flange untuk semua nozzle, dipilih flange standart type welding neck dengan dimensi :

- Nozzle A = Nozzle pemasukan Etanol
- Nozzle B = Nozzle pemasukan Udara H2SO4
- Nozzle C = Nozzle pemasukan air pendingin
- Nozzle D = Nozzle pengeluaran produk liquid
- Nozzle E = Nozzle untuk manhole
- Nozzle F = Nozzle pengeluaran air pendingin
- Nozzle G = Nozzle pengeluaran produk gas
- NPS = Ukuran pipa nominal, in
- A = Diameter luar flange, in
- T = Ketebalan minimum flange, in
- R = Diameter luar bagian yang menonjol, in
- E = Diameter hubungana atas, in
- K = Diameter hubungan pada titik pengelasan, in
- L = Panjang julakan, in
- B = Diameter dalam flange, in

| Nozzle | NPS | A | T | R | E | K | L |
|---|---|---|---|---|---|---|---|
| A | 2 | 7 1/2 | 15/16 | 5 | 4 1/4 | 3.5 | 2 3/4 |
| B | 2 | 9 | 15/16. | 6 3/16. | 5 5/16. | 4.50 | 3 |
| C | 20 | 3 1/2 | 7/16` | 1 3/8 | 1.3/16 | 0.84 | 1 7/8 |
| D | 1/2 | 7 1/2 | 15/16 | 5 | 4 1/4 | 3.5 | 2 3/4 |
| E | 1 | 27.5 | 1 11/16 | 23 | 22 | 20 | 5 11/16 |
| F | 1/2 | 3 1/2 | 7/16` | 1 3/8 | 1.3/16 | 0.84 | 1 7/8 |
| G | 16 | 25 | 1 9/16. | 21 | 19 7/8. | 18 | 5 1/2 |

**6. Flange, Bolting dan Gasket**

**a. Flange**

- Bahan konstruksi = HAS SA 240 Grade M Type 316
- Tensile strength minimum = 75000 psia
- Allowable stress (f) = 15000
- Tebal flange = 1.1551 in
- Diameter dalam (Di) = 15.5306 in
- Diameter luar (Do) = 16.2806 in
- Type flange = Ring Hange Loss Type

**b. Bolting**

- Bahan konstruksi = HAS SA 193 Grade B6 Type 416
- Tensile strength minimum = 75000 psia
- Allowable stress (f) = 15000
- Ukuran Baut = 1/2 in
- Jumlah Baut = 4 buah

**c. Gasket**

- Bahan konstruksi = Asbestos Filled Stainless steel
- Gasket factor (m) = 3.75
- min design seating stress (y) = 9000 psia
- Tebal Gasket (n) = 0.0055 in

**7. Sistem Penyangga Reaktor**

- Jenis = Kolom I-Beam
- Width of flange (b) = 5.0000 in
- Depth of beam (h) = 12 in
- Area of section (Ay) = 9.2600 $in^2$
- Axis (r) = 4.8300 in
- Jumlah = 4 buah
- Ukuran I-beam = 12 x 5 in
- Panjang (L) = 43.1513 in

**8. Base Plate**

- Ukuran = 1/8 in
- Root area = 1 1/4 in

- Bolt spacing = 1 1/5 in
- Minimum radial distance = 2 in
- Edge distance = 1 1/2 in
- Nut dimension = 2 3/8 in
- Maximum fillet radius = 5/8 in

**9. Lug**

- Lebar = 9.3035 in
- Tebal = 0.3985 in
- Tinggi = 10.6005 in

**10. Gusset**

- Lebar = 15.6965 in
- Tebal = 0.1494 in
- Tinggi = 10.6005 in

**11. Sistem Pondasi**

- Luas Atas = 15 x 15 in
- Luas Bawah = 40 x 40 in
- Tinggi Pondasi = 20 in
- Luas Permukaan Tanah rata-rata = 1600 $in^2$
- Bahan = Pasir, Semen dan Batuan kecil (Gr