BAB VI
PERANCANGAN ALAT UTAMA

Nama Alat : Reaktor
Kode Alat : R-130
Fungsi : Untuk mereaksikan antara kalsium hidroksida $Ca(OH)_2$ dan asam sulfat (H_2SO_4) sehingga terbentuk $CaSO_4$.
Tipe : Berbentuk silinder tegak dengan tutup atas standard dished dan tutup bawah berbentuk conical dengan sudut 120^0

Kondisi Operasi

- Rate feed masuk = 24.083,042 kg/jam = 53.093,474 lb/jam
  = 14,748 lb/s
- Rate pendingin masuk = 355,412 kg/jam = 783,541 lb/jam
- Suhu = 93 ^0C = 366,15 K = 199,4 ^0F
- Tekanan = 1 atm = 14,696 psia = 0 psig
  = 101325 Pa

Direncanakan

- Bahan Konstruksi = High Alloy Steel SA 240 Grade M Type 316
- Tutup Reaktor Atas = Standard dished
- Tutup Reaktor Bawah = Conical dengan sudut puncak 120^0
- Allowable stress (f) = 18.750 psi
- Tipe Pengelasan = Double welded butt joint
- E = 0,8
- Faktor korosi (C) = 1/16 = 0,06 in

Neraca Massa Masuk Reaktor

Komponen	BM	Masuk		x_i	$BM.x_i$
		kg/jam	kmol/jam		
$CaCO_3$	100	7.413,487	74,135	0,1139	11,392
$MgCO_3$	83	71,946	0,867	0,0013	0,111
SiO_2	60	27,264	0,454	0,0007	0,042
Al_2O_3	102	12,875	0,126	0,0002	0,020
Fe_2O_3	160	18,933	0,118	0,0002	0,029
$CaSO_4$	136	6,059	0,045	0,0001	0,009
H_2O	18	8.959,194	497,733	0,7649	13,767
H_2SO_4	98	7.573,284	77,278	0,1188	11,638
Total		24.083,042	650,757	1,0000	37,008

Neraca Massa Keluar Reaktor

Komponen	BM	Masuk	x_i	$BM.x_i$

Komponen	BM	kg/jam	kmol/jam	x_i	$BM.x_i$
$CaCO_3$	100	370,67	3,71	0,01	0,64
$MgCO_3$	83	71,95	0,87	0,00	0,12
SiO_2	60	27,26	0,45	0,00	0,05
Al_2O_3	102	12,87	0,13	0,00	0,02
Fe_2O_3	160	18,93	0,12	0,00	0,03
$CaSO_4$	136	6,06	0,04	0,00	0,01
H_2O	18	7.691,49	427,30	0,74	13,25
H_2SO_4	98	671,33	6,85	0,01	1,16
$CaSO_4.2H_2O$	172	12.113,64	70,43	0,12	20,87
CO_2	44	3.098,84	70,43	0,12	5,34
Jumlah		23.613,16	580,33	1,00	41,50

- Kinetika Reaksi

$$CaCO_3 + H_2SO_4 + H_2O \xrightarrow{95\%} CaSO_3.2H_2O + CO_2$$

waktu tinggal = 10 menit (US Patent 3929416)

reaksi orde = 1 (Primiceriometri, 2013)

Menghitung nilai ε :

$$\varepsilon = \frac{\text{koefisien produk} - \text{koefisien reaktan}}{\text{koefisien reaktan}}$$

$$= \frac{2 - 3}{3} = -\frac{1}{2}$$

Rumus kinetika reaksi ($\varepsilon_A \neq 0$) orde 1

$$k\,T = \frac{X_A (1 + \varepsilon_A X_A)}{1 - X_A}$$ (Levenspiel, tabel 5.2 hal 112)

$$k \quad 10 = \frac{0,499}{1 - 0,95}$$

$$k \quad 10 = \frac{0,50}{0,05}$$

$$= 1,00 \ \text{min}^{-1}$$

sehingga

$-r_A = k \ C_A$

$= 1,00 \ C_A$

A. Menghitung Volume Reaktor

- Menghitung densitas campuran masuk

Komponen	x_i	ρ (kg/m³)	ρ_i . xi
$CaCO_3$	0,1139	2710	308,726

$MgCO_3$	0,0013	3307	4,405
SiO_2	0,0007	2334	1,630
Al_2O_3	0,0002	3982,6	0,772
Fe_2O_3	0,0002	5179,8	0,942
$CaSO_4$	0,0001	2320	0,159
H_2O	0,7649	995,65	761,526
H_2SO_4	0,1188	1830	217,315
Total	1,0000	22659,1	1.295,475

$\rho_{campuran} = \dfrac{\sum \rho_i \cdot xi}{\sum xi}$

$= \dfrac{1.295,475}{1}$

$= 1.295,475 \text{ kg/m}^3$

$= 80,874 \text{ lb/ft}^3$

- Menghitung volume reaktor

Rate volumetrik $= \dfrac{\text{Bahan masuk}}{\rho_{campuran}}$

$= \dfrac{24.083,042 \text{ kg/jam}}{1.295,475 \text{ kg/m}^3}$

$= 18,590 \text{ m}^3\text{/jam}$

$= 656,504 \text{ ft}^3\text{/jam}$

Volume liquid $= 656,504 \text{ ft}^3$

Volume ruang kosong untuk reaktor berpengaduk dan coil $= 30\% \ V_{total}$

Volume total = Volume liquid + Volume ruang kosong

$V_{total} = 656,504 + 30\% \ V_{total}$

$70\% \ V_{total} = 656,504$

$V_{total} = 937,863 \text{ ft}^3$

B. Menentukan dimensi reaktor

- Diameter Vessel

Asumsi : Ls = 1,5 di

$V_{total} = V_{tutup\ bawah} + V_{silinder} + V_{tutup\ atas}$

$V_{total} = \dfrac{\pi\ di^3}{24 \tan 1/2\ \alpha} + \dfrac{\pi}{4} \times di^2 \times L_s + 0,0847\ di^3$

$= \dfrac{3,14}{24} \times \dfrac{di^3}{\tan 60^o} + \dfrac{3,14}{24}\ 1,5\ di^3 + 0,0847\ di^3$

$937,863 \text{ ft}^3 = 0,076\ di^3 + 0,19625\ di^3 + 0,0847\ di^3$

$937,863 \text{ ft}^3 = 0,356\ di^3$

$di^3 = 2.630,850 \text{ ft}^3$

$di = 13,805 \text{ ft}$

$di = 165,658 \text{ in}$

- Menghitung volume liquid dalam silinder (V_{Ls})

$$V_{Ls} = V_{liquid} - V_{tutup\ bawah}$$

$$= 656,504 - \frac{\pi\ di^3}{24 \tan 1/2\ \alpha}$$

$$= 656,504 - 0,076\ di^3$$

$$= 656,504 - 198,726$$

$$= 457,778\ ft^3$$

- Menghitung tinggi liquid dalam silinder (L_{Ls})

$$L_{Ls} = \frac{V_{Ls}}{(\pi/4) \times di^2}$$

$$= \frac{457,778}{149,601}$$

$$= 3,060\ ft$$

$$= 36,720\ in$$

- Menghitung tekanan design (Pi)

$$P_i = P_{atm} + P_{hidrostatik}$$

$$P_{hidrostatik} = \frac{\rho \times (L_{Ls} - 1)}{144}$$

$$= \frac{80,874 \times 2,060}{144}$$

$$= \frac{166,600}{144}$$

$$= 1,157\ psia$$

$$P_i = P_{atm} + P_{hidrostatik}$$

$$= 14,696 + 1,157$$

$$= 15,853\ psia$$

$$= 1,157\ psig$$

- Menghitung tebal silinder (t_s)

$$t_s = \frac{Pi \times di}{2\ (f \times E - 0.6 \times Pi)} + C$$

$$= \frac{1,157 \times 165,658}{2 \times (18750 \times 0,8 - 0,6 \times 1,157)} + \frac{1}{16}$$

$$= \frac{191,658}{29.998,612} + \frac{1}{16}$$

$$= 0,006 + \frac{1}{16}$$

$$= \frac{1,102}{16} \approx \frac{3}{16}\ in$$

- Standarisasi do

$$d_o = d_i + 2t_s$$

$= 165{,}658 + 0{,}375$

$= 166{,}033$ in

≈ 168 in

Berdasarkan buku Brownell tabel 5.7 halaman 91

$d_0 = 168$ in

$t_s = \frac{3}{16}$ in

} nilai r dan icr tidak ada

maka nilai t_s dinaikkan menjadi 1/2 in

$d_0 = 168$ in

$t_s = \frac{1}{2}$ in

} icr = $10 \frac{1}{8}$ in

r = 144 in

maka

$di_{baru} = d_o - 2t_s$

$= 168 - 1{,}00$

$= 167$ in

$= 13{,}9167$ ft

Cek hubungan Ls dengan di

$V_{total} = V_{tutup\ bawah} + V_{silinder} + V_{tutup\ atas}$

$$V_{total} = \frac{\pi\ di^3}{24 \tan 1/2\ \alpha} + \frac{\pi}{4} \times di^2 \times L_s + 0{,}0847\ di^3$$

$$= \frac{3{,}14}{24} \times \frac{2695{,}29}{\tan 60^0} + \frac{3{,}14}{24}\ 193{,}674\ L_s \times 228{,}291$$

$937{,}863 = 203{,}593 + 25{,}339\ L_s + 228{,}291$

$25{,}339\ L_s = 505{,}978$

$L_s = 19{,}968$ ft

$= 239{,}621$ in

$$\frac{L_s}{di} = \frac{19{,}968}{13{,}9167} = 1{,}43 < 1{,}5 \quad \text{(Memenuhi)}$$

- Menghitung dimensi tutup atas (standart dished)

Berdasarkan buku brownell, tabel 5.7 halaman 91

$d_0 = 168$ in

$t_s = \frac{1}{2}$ in

} icr = $10 \frac{1}{8}$ in

r = 144 in

dari tabel 5.6 halaman 88

sf = 4,5 in

Tebal tutup atas (tha)

$$tha = \frac{0.885 \times P_i \times r}{(f \times E - 0.1\ P_i)} + C$$

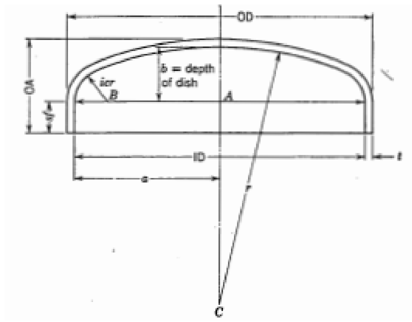
$$= \frac{0,885 \quad x \quad 1,157 \quad x \quad 144}{18.750 \quad x \quad 0,8 - \quad 0,1 \quad x \quad 1,157} + \frac{1}{16}$$

$$= \frac{147,441}{14.999,884} + \frac{1}{16}$$

$$= \frac{0,157}{16} + \frac{1}{16}$$

$$= \frac{1,157}{16} \approx \frac{3}{16} \text{ in}$$

Tinggi tutup atas (ha)



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

$= \frac{167,000}{2}$

= 83,5 in

= 6,958 ft

BC = r - icr

= 144 - 10,125

= 133,875 in

= 11,1563 ft

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

= 83,5 - 10,125

= 73,375 in

= 6,115 ft

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

= 144 - 111,976

= 32,024 in

= 2,669 ft

ha = th + b + sf

= 0,188 + 32,024 + 4,5

= 36,711 in

= 3,059 ft

- Menghitung dimensi tutup bawah (conical)

Tebal tutup bawah (thb)

thb $= \frac{P_i \text{ x } d_i}{2 \cos 1/2\, \alpha \text{ (f x E - 0,6 x } P_i)} + C$

$$= \frac{1,157 \text{ x } 167}{1 \text{ x } (\quad 18750 \quad x \quad 0,8 \quad - \quad 0,1 \quad x \quad 1,157 \quad)} + \frac{1}{16}$$

$= \frac{193,210}{\quad} + \frac{1}{\quad}$

$$= \frac{14.999,884}{} \quad 16$$

$$= \frac{0,206}{16} + \frac{1}{16}$$

$$= \frac{1,206}{16} \approx \frac{3}{16} \text{ in}$$

Tinggi tutup bawah (hb)

$$hb = \frac{1/2\ d_i}{\tan 1/2\ \alpha}$$

$$= \frac{83,500}{1,732}$$

= 48,2087 in

= 4,017 ft

- Menghitung tinggi reaktor

Tinggi reaktor = Tinggi (tutup atas + silinder + tutup bawah)

= 36,711 + 239,621 + 48,2087

= 324,541 in

Kesimpulan dimensi reaktor

d_o	=	168 in	tha	=	1/5 in
d_i	=	167 in	ha	=	36,711 in
L_s	=	239,621 in	thb	=	1/5 in
t_s	=	1/5 in	hb	=	48,2087 in

Tinggi reaktor = 324,541 in

C. Perhitungan Dimensi Pengaduk

Perencanaan pengaduk

Jenis pengaduk = Axial turbin 6 blades 45^0

Bahan impeller = High Alloy Steel SA 240 Grade M type 316

Bahan poros pengaduk = Hot Roller SAE 1020

Berdasarkan buku Geankoplis tabel 3.4-1, hal 144 :

D_t/D_i = 0,3 to 0,5

Z_i/D_i = 1/4

L/D_i = 1/3

W/D_i = 1/5

J/D_t = 0,08333

Dimana :

D_t = Diameter dalam silinder

D_i = Diameter impeller

Z_i = Tinggi impeller dari dasar tangki

Z_L = Tinggi liquid dalam silinder

W = Lebar baffle (daun) impeller

L = Panjang impeller

- Menentukan diameter impeller

$$\frac{D_t}{} = 0,3$$

D_i = 0,3

$D_i = D_t \times 0{,}4$

$= 167 \times 0{,}4$

$= 66{,}800$ in

$= 5{,}567$ ft

- Menentukan tinggi impeller dari dasar tangki

$$\frac{Z_i}{D_i} = \frac{1}{4}$$

$$Z_i = \frac{D_i}{4}$$

$$= \frac{66{,}800}{4}$$

$= 16{,}700$ in

$= 1{,}39167$ ft

- Menentukan panjang impeller

$$\frac{L}{D_i} = \frac{1}{3}$$

$$L = \frac{D_i}{3}$$

$$= \frac{66{,}800}{3}$$

$= 22{,}267$ in

$= 1{,}85556$ ft

- Menentukan lebar impeller

$$\frac{W}{D_i} = \frac{1}{5}$$

$$W = \frac{D_i}{5}$$

$$= \frac{66{,}800}{5}$$

$= 13{,}360$ in

$= 1{,}11333$ ft

- Menentukan tebal blades

$$\frac{J}{D_t} = \frac{1}{12}$$

$$J = \frac{D_t}{12}$$

$$= \frac{167{,}000}{12}$$

$= 13{,}917$ in

$= 1{,}15972$ ft

- Menentukan jenis pengaduk

Dari perbandingan Da/W, Geankoplis halaman 144, didapatkan Da/W 5

$$\frac{Da}{W} = \frac{5,567}{1,113}$$

$$= 5$$

maka jenis pengaduk yang digunakan adalah *Flat Six Blade Turbine With Disk*

- Menentukan jumlah pengaduk

$$n = \frac{H_{liquida}}{2 \times D_i^2}$$

$$= \frac{3,060}{2 \times 5,567^2}$$

$$= \frac{3,060}{61,976}$$

$$= 0,049$$

$$\approx 1 \text{ buah}$$

- Menghitung Bilangan Reynold

$$N_{Re} = \frac{D_i^2 \times n \times \rho}{\mu}$$

Keterangan :

D_i = diameter impeller

ρ = densitas bahan

μ = viskositas bahan = 1,1 cp = 0,00074 lb/ft.s

n = kecepatan putaran pengadukan = 60 rpm = 1 rps

$$N_{Re} = \frac{30,988 \times 1 \times 80,874}{0,00074}$$

$$= \frac{2506,101}{0,00074}$$

$$= 3.390.288,748$$ Aliran Turbulen (N_{Re} > 2100)

- Menghitung daya pengaduk

$$P = \frac{\phi \times \rho \times n^3 \times D_i^5}{g_c}$$

dimana :

P = daya pengaduk

ϕ = power number

ρ = densitas bahan

D_i = diameter impeller

g_c = 32,174 $lb_m.ft/s^2.lb_f$

n = 60 rpm = 1 rps

dari buku G.G. Brown gambar 477 hal 507, didapatkan ϕ = 6

$$P = \frac{6 \times 80,874 \times 1,000 \times 5345,349}{32,174}$$

$= \dfrac{2.593.794,387}{32,174}$

= 80.617,716 lb.ft/s

= 146,578 Hp

≈ 147 Hp

Kehilangan - kehilangan daya

Gain losses (kebocoran daya pada proses dan bearing) diperkirakan 10% dari daya masuk

Transmission System Losses (Kebocoran belt atau gear) diperkirakan 15% dari daya masuk

sehingga daya yang dibutuhkan :

P yang dibutuhkan = (0,1 + 0,15) P + P

= 0,25 P + P

= 36,8 + 147

= 184 Hp

- Diameter poros

$T = \dfrac{\pi \; S \; D^2}{16}$ (Hesse, pers. 16-1 hal. 465)

dimana :

T = momen puntir (lb.in) $= \dfrac{63025 \; H}{N}$ (Hesse, hal 469)

H = daya motor pada poros = 184 Hp

n = putaran pengaduk = 60 rpm = 1 rps

sehingga

$T = \dfrac{63025 \; H}{N}$

$= \dfrac{63025 \; x \; 184}{60}$

= 193.014,0625 lb.in

Berdasarkan buku Hesse tabel 16-1 hal. 467 untuk bahan Hot Rolled Steel SAE 1020 mengandung karbon = 20% dengan batas = 36000 lb/in^2

S = maksimm design shering stress yang diijinkan

= 20% x 36000

= 7.200 lb/in^2

maka didapatkan diameter poros pengaduk (D)

$D = \left(\dfrac{16 \; x \; T}{\pi \; x \; S} \right)^{1/2}$

$= \left(\dfrac{16 \; x \; 193.014,0625}{\pi \; x \; 7.200} \right)^{1/2}$

$= \left(\dfrac{3.088.225,0000}{22.608} \right)^{1/2}$

= 11,688 in

- Menentukan panjang poros

  $L = h + l - Z_i$

  Keterangan :

  L = panjang poros (ft)

  Z_i = jarak impeller dari dasar tangki = 16,700 in = 1,392 ft

  l = panjang poros diatas bejana tangki = 22,267 in = 1,856 ft

  h = tinggi silinder + tinggi tutup atas

  = 239,621 + 36,711

  = 276,332 in = 23,0277 ft

  Jadi, panjang poros pengaduk :

  $L = h + l - Z_i$

  = 276,332 + 22,267 - 16,700

  = 281,899 in

  = 23,492 ft

  Kesimpulan dimensi pengaduk

  Type : = Axial turbin 6 blades 45^0

D_i	=	66,800	in	=	5,567	ft	Daya	=	184 Hp
Z_i	=	16,700	in	=	1,392	ft	Jumlah	=	1
W	=	13,360	in	=	1,113	ft			
L	=	22,267	in	=	1,856	ft			
J	=	13,917	in	=	1,160	ft			

  Diameter poros = 11,688 in = 0,97396 ft

  Panjang poros = 281,899 in = 23,4916 ft

D. Perhitungan Jaket Pendingin

Dalam reaktor reaksi yang terjadi adalah reaksi eksotermis pada suhu 93^0C, jadi dibutuhkan jaket pendingin dengan air sebagai media pendingin untuk menjaga agar suhu tetap 93^0C

Dasar Perancangan

Rate massa air pendingin	=	355,412	kg/jam	=	783,553	lb/jam
Q	=	58.134,523	kkal/jam			
	=	230.542,33	btu/jam			
Bentuk coil	=	Spiral				
Rd min	=	0,001				
Kecepatan putaran (N)	=	60	rpm	=	3600	rph
Suhu bahan masuk (T_1)	=	93	^{0}C	=	366,15	K
Diameter pengaduk (D_a)	=	66,800	in	=	5,567	ft
Diameter tangki (D_o)	=	168,000	in	=	14,000	ft
Diameter dalam tangki (D_i)	=	167,000	in	=	13,917	ft
Tinggi silinder (L_s)	=	239,621	in	=	19,968	ft
Tinggi liquid dalam silinder (L_{ls})	=	36,720	in	=	3,060	ft
Suhu pendingin masuk	=	27	^{0}C	=	300,15	K
Suhu pendingin keluar	=	45	^{0}C	=	318,15	K

Densitas pendingin masuk = 0,99 g/cm^3 = 62,0318 lb/ft^3

- Menghitung ΔT_{LMTD}

	Fluida Panas (^0C)		Fluida Panas (^0C)	ΔT
ΔT_2	93	Lower Temp	27	66
ΔT_1	93	Higher Temp	45	48

$$\Delta T_{LMTD} = \frac{\Delta T_2 - \Delta T_1}{\ln \Delta T_2/\Delta T_1}$$

$$= \frac{18}{0,318}$$

$$= 56,523\ ^0C = 133,742\ ^0F$$

- Menghitung luas transfer panas

Untuk cold fluid dimana water dan hot fluid dengan viskositas light organic nilai Ud berkisar antara 75 - 150 $Btu/ft^2.^0F.h$

Diambil nilai Ud = 100 $btu/ft^2.^0F.h$

Maka nilai luas transfer panas dapat dihitung dengan persamaan berikut,

$$A = \frac{Q}{Ud \times \Delta T_{LMTD}}$$

$$= \frac{230.542,33}{100 \times 133,742}$$

$$= 17,238\ ft^2 = 1,601\ m^2$$

nilai A <120 ft^2 maka menggunakan jaket

- Menghitung luas selubung reaktor

$$L = \pi \times D_o \times L_s$$

$$= 3,14 \times 14,000 \times 19,968$$

$$= 877,811\ ft^2$$

- Menghitung volume pendingin

$$V_{pendingin} = \frac{\text{massa pendingin}}{\rho \text{ pendingin}}$$

$$= \frac{783,553}{62,032}$$

$$= 12,6315\ ft^3/jam$$

- Menghitung tekanan design (p_i)

$$P_i = P_{atm} + P_{hidrostatik}$$

$$P_{hidrostatik} = \frac{\rho \times (L_{Ls} - 1)}{144}$$

$$= \frac{62,032 \times 2,060}{144}$$

$$= \frac{127,786}{144}$$

$$= 0,887\ psia$$

$P_i = P_{atm} + P_{hidrostatik}$
$= 14{,}696 + 0{,}887$
$= 15{,}583$ psia
$= 0{,}887$ psig

- Menghitung dimensi jaket

Jika tinggi jaket (L_{sj}) = tinggi liquid dalam silinde = 3,060 ft
Tinggi jaket bawah (h_{bj}) = tinggi tutup bawah = 4,017 ft

$V_{jaket} = V_{tutup\ bawah} + V_{silinder}$

$$V_{jaket} = \frac{\pi}{4} \text{ x } d_{ij}^2 \text{ x } \frac{1}{3} H_{bj} + \frac{\pi}{4} \text{ x } d_{ij}^2 \text{ x } L_{sj}$$

$12{,}6315 = 1{,}05\ d_{ii}^2 + 0{,}79\ d_{ii}^2 \text{ x } 3{,}060$
$12{,}6315 = 1{,}051\ d_{ii}^2 + 2{,}402\ d_{ii}^2$
$d_{ii}^2 = 3{,}658$
$d_{ij} = 1{,}913$ ft $= 22{,}950$ in

- Menghitung tebal jaket (t_j)

$$t_j = \frac{Pi \times d_{ij}}{2\,(f \times E - 0.6 \times Pi)} + C$$

$$= \frac{0{,}887 \text{ x } 22{,}950}{2 \times (18750 \times 0{,}8 - 0{,}6 \times 0{,}887)} + \frac{1}{16}$$

$$= \frac{20{,}366}{29.998{,}935} + \frac{1}{16}$$

$$= 7{,}E\text{-}04 + \frac{1}{16}$$

$$= \frac{1{,}011}{16} \approx \frac{3}{16} \text{ in}$$

sehingga

$d_{oj} = d_{ij} + 2\ t_{sj}$
$= 22{,}950 + 0{,}375$
$= 23{,}325$ in $= 279{,}905$ ft

Standarisasi d_{oj} (Berdasarkan Brownell tabel 5.7 halaman 90), didapatkan

$d_{oj} = 24$ in $= 2$ ft

maka

$d_{ij} = d_{oj} - 2\ t_{sj}$
$= 24 - 0{,}375$
$= 23{,}625$ in $= 1{,}969$ ft

$$V_{silinder} = \frac{\pi}{4} \text{ x } d_{ij}^2 \text{ x } L_{sj}$$
$= 9{,}310\ ft^3$

$$V_{tutup\ bawah} = \frac{\pi\, d_{ij}^3}{}$$

$$- \quad 24 \tan 1/2\ \alpha$$

$= 0,02\ d_{ij}^{3}$

$= 0,176\ ft^{3}$

- Menentukan tebal jaket bagian bawah

$$th_{bj} = \frac{P_i \times d_{ij}}{2 \cos 1/2\ \alpha\ (f \times E - 0,6 \times P_i)} + C$$

$$= \frac{0,887 \times 23,625}{1 \times (18750 \times 0,8 - 0,6 \times 0,887)} + \frac{1}{16}$$

$$= \frac{20,965}{14.999,468} + \frac{1}{16}$$

$$= \frac{0,022}{16} + \frac{1}{16}$$

$$= \frac{1,022}{16} \approx \frac{3}{16}\ in$$

Tinggi jaket keseluruhan = Tinggi jaket silinder + Tinggi jaket bawah

= 7,077 ft

= 84,929 in

Dari perhitungan, diperoleh dimensi jaket sebagai berikut :

- Bahan konstruksi = High alloy stainless SA 240 Grade M type 316
- Diameter luar (d_{oj}) = 40 in = 3,333 ft
- Diameter dalam (d_{ij}) = 23,625 in = 1,969 ft
- Tebal jaket (t_j) = 3/16 in
- Tinggi jaket (L_{sj}) = 84,929 in = 7,077 ft

E. Perhitungan Nozzle

1. Nozzle untuk pemasukkan bahan baku (A)

Rate umpan masuk = 8.936,475 kg/jam = 19.701,352 lb/jam

Densitas umpan (ρ) = 2.454,59 kg/m^3 = 153,235 lb/ft^3

$$\text{Rate volumetrik (Q)} = \frac{\text{Rate umpan masuk}}{\rho}$$

$$= \frac{19.701,352}{153,235}$$

= 128,569 ft^3/jam

= 0,036 ft^3/s

Asumsi jika aliran turbulent

$Di_{optimum} = 3,9 \times Q^{0,45} \times \rho^{0,13}$

= 1,675 in

= 0,140 ft

Maka dipilih ukuran pipa yang dipilih 3 in sch 40 (Appendix K, Brownell)

OD = 3,5 in = 0,292 ft

ID = 3,07 in = 0,256 ft

a' = 7,39 in^2 = 0,051 ft^2

Pengecekan bilangan reynold

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

$$= \frac{5,473 \times 0,256}{0,000 \times 0,051}$$

= 99.460,781 (aliran turbulen)

Spesifikasi nozzle (Appendix F, Brownell)

Size	=	3	
OD of pipe	=	3,5	in
Flange nozzle thickness (n)	=	0,3	in
Diameter of hole in reinforcing plate (DR)	=	3 5/8	in
Length if 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	=		
- Reguler, type H	=	7	in
- Low, Type C	=	3 1/2	in

2. Nozzle untuk pemasukkan larutan asam sulfat (B)

Rate umpan masuk = 15.146,567 kg/jam = 33.392,122 lb/jam

Densitas umpan (ρ) = 1.412,83 kg/m^3 = 88,200 lb/ft^3

$$\text{Rate volumetrik (Q)} = \frac{\text{Rate umpan masuk}}{\rho}$$

$$= \frac{33.392,122}{88,200}$$

= 378,596 ft^3/jam

= 0,105 ft^3/s

Asumsi jika aliran turbulent

$Di_{optimum}$ = $3,9 \times Q^{0,45} \times \rho^{0,13}$

= 2,534 in

= 0,211 ft

Maka dipilih ukuran pipa yang dipilih 3 in sch 40

OD = 3,5 in = 0,292 ft

ID = 3,07 in = 0,256 ft

a' = 7,39 in^2 = 0,051 ft^2

Pengecekan bilangan reynold

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

$$= \frac{9,276 \times 0,256}{0,002 \times 0,051}$$

= 27.363,044 (aliran turbulen)

Spesifikasi nozzle

Size	=	3	
OD of pipe	=	3,5	in
Flange nozzle thickness (n)	=	0,3	in
Diameter of hole in reinforcing plate (DR)	=	3 5/8	in
Length if 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	=		
- Reguler, type H	=	7	in
- Low, Type C	=	3 1/2	in

3. Nozzle pengeluaran produk gypsum (C)

Rate umpan masuk	=	20.984,204	kg/jam	=	46.261,776	lb/jam
Densitas umpan (ρ)	=	2.003,09	kg/m^3	=	125,049	lb/ft^3

Rate volumetrik (Q) $= \frac{\text{Rate umpan masuk}}{\rho}$

$= \frac{46.261,776}{125,049}$

= 369,950 ft^3/jam

= 0,103 ft^3/s

Asumsi jika aliran turbulent

$Di_{optimum} = 3,9 \times Q^{0,45} \times \rho^{0,13}$

= 2,624 in

= 0,219 ft

Maka dipilih ukuran pipa yang dipilih 3 in sch 40

OD	=	3,5	in	=	0,292	ft
ID	=	3,07	in	=	0,256	ft
a'	=	7,39	in^2	=	0,051	ft^2

Pengecekan bilangan reynold

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

$$= \frac{12,850 \times 0,256}{0,001 \times 0,051}$$

= 80.076,485 (aliran turbulen)

Spesifikasi nozzle

Size	=	3	
OD of pipe	=	3,5	in

Flange nozzle thickness (n)	=	0,3	in
Diameter of hole in reinforcing plate (DR)	=	3 5/8	in
Length if 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	=		
- Reguler, type H	=	7	in
- Low, Type C	=	3 1/2	in

4. Nozzle untuk pengeluaran karbondioksida (D)

Rate umpan masuk	=	3.098,838	kg/jam	=	6.831,698	lb/jam
Densitas umpan (ρ)	=	1,464	kg/m^3	=	125,049	lb/ft^3
Viskositas umpan (μ)	=	1.824,816	cp	=	1,226	lb/ft.s

Rate volumetrik (Q) $= \dfrac{\text{Rate umpan masuk}}{\rho}$

$= \dfrac{6.831,698}{125,049}$

$=$ 54,632 ft^3/jam

$=$ 0,015 ft^3/s

Asumsi jika aliran laminer

$Di_{\ optimum} = 3,0 \times Q^{0,36} \times \mu^{0,18}$

$=$ 0,608 in

$=$ 0,051 ft

Maka dipilih ukuran pipa yang dipilih 3 in sch 40

OD	=	3,5	in	=	0,292	ft
ID	=	3,07	in	=	0,256	ft
a'	=	7,39	in^2	=	0,051	ft^2

Pengecekan bilangan reynold

$N_{Re} = \dfrac{G \times ID}{\mu \times a'}$

$= \dfrac{1,8977 \times 0,256}{1,E+00 \times 0,051}$

$=$ 7,715 (aliran laminer)

Spesifikasi nozzle

Size	=	3	
OD of pipe	=	3,5	in
Flange nozzle thickness (n)	=	0,3	in
Diameter of hole in reinforcing plate (DR)	=	3 5/8	in
Length if 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	=		
- Reguler, type H	=	7	in
- Low, Type C	=	3 1/2	in

5. Nozzle untuk air pendingin masuk (E)

Rate umpan masuk	=	355,412	kg/jam	=	783,541	lb/jam
Densitas umpan (ρ)	=	1,00	kg/m^3	=	0,063	lb/ft^3
Viskositas umpan (μ)	=	0,001	cp	=	0,000	lb/ft.s

Rate volumetrik (Q) $= \dfrac{\text{Rate umpan masuk}}{\rho}$

$= \dfrac{783{,}541}{0{,}063}$

$= 12.491{,}171$ ft^3/jam

$= 3{,}470$ ft^3/s

Asumsi jika aliran laminer

$Di_{\text{optimum}} = 3{,}0 \times Q^{0,36} \times \mu^{0,18}$

$= 1{,}054$ in

$= 0{,}088$ ft

Maka dipilih ukuran pipa yang dipilih 3 in sch 40

OD	=	3,5	in	=	0,292	ft
ID	=	3,07	in	=	0,256	ft
a'	=	7,39	in^2	=	0,051	ft^2

Pengecekan bilangan reynold

$N_{Re} = \dfrac{G \times ID}{\mu \times a'}$

$= \dfrac{0{,}218 \times 0{,}256}{0{,}001 \times 0{,}051}$

$= 1.356{,}265$ (aliran laminer)

Spesifikasi nozzle

Size	=	3	
OD of pipe	=	3,5	in
Flange nozzle thickness (n)	=	0,3	in
Diameter of hole in reinforcing plate (DR)	=	3 5/8	in
Length if 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	=		
- Reguler, type H	=	7	in
- Low, Type C	=	3 1/2	in

6. Nozzle untuk air pendingin (F)

Rate umpan keluar	=	355,412	kg/jam	=	783,541	lb/jam
Densitas umpan (ρ)	=	1,113	kg/m^3	=	0,069	lb/ft^3

Viskositas umpan (μ) = 0,001 cp = 0,000 lb/ft.s

Rate volumetrik (Q) $= \dfrac{\text{Rate umpan masuk}}{\rho}$

$= \dfrac{783{,}541}{0{,}069}$

= 11280,345 ft^3/jam

= 3,133 ft^3/s

Asumsi jika aliran turbulent

$Di_{optimum}$ = $3{,}9 \times Q^{0,45} \times \rho^{0,13}$

= 4,610 in

= 0,384 ft

Maka dipilih ukuran pipa yang dipilih 6 in sch 40

OD	=	6,63	in	=	0,552	ft
ID	=	6,07	in	=	0,505	ft
a'	=	28,9	in^2	=	0,201	ft^2

Pengecekan bilangan reynold

$N_{Re} = \dfrac{G \times ID}{\mu \times a'}$

$= \dfrac{0{,}2177 \times 0{,}505}{4{,}E\text{-}07 \times 0{,}201}$

= 1.336.754,145 (aliran turbulen)

Spesifikasi nozzle

Size	=	6	
OD of pipe	=	6,625	in
Flange nozzle thickness (n)	=	0,432	in
Diameter of hole in reinforcing plate (DR)	=	6 3/4	in
Length if side of reinforcing plate (L)	=	16 1/4	in
Width of reinforcing plate (W)	=	20 1/4	in
Distance, shell to flange face, outside (J)	=	8	in
Distance, shell to flange face, inside (K)	=	6	in
Distance from bottom of tank to center of nozzle	=		
- Reguler, type H	=	11	in
- Low, Type C	=	8 1/8	in

7. Nozzle manhole (G)

Lubang manhole dibuat berdasarkan standar yang ada yaitu 20 in

Spesifikasi nozzle

Maka dipilih ukuran pipa yang dipilih 20 in sch 40

OD	=	20	in	=	1,667	ft
ID	=	18,81	in	=	1,568	ft
a'	=	278	in^2	=	1,931	ft^2

Spesifikasi nozzle

Size	=	20

OD of pipe	=	20	in
Flange nozzle thickness (n)	=	1/2	in
Diameter of hole in reinforcing plate (DR)	=	20 1/8	in
Length if side of reinforcing plate (L)	=	43	in
Width of reinforcing plate (W)	=	52 1/2	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	=		
- Reguler, type H	=	24	in
- Low, Type C	=	21 1/2	in

8. Nozzle HandHole (H)

Lubang untuk handhole dibuat sesuai standar yaitu 6 in

Maka dipilih ukuran pipa yang dipilih 6 in sch 40

OD	=	6,63	in	=	0,552	ft
ID	=	6,07	in	=	0,505	ft
a'	=	28,9	in^2	=	0,201	ft^2

Spesifikasi nozzle

Size	=	6	
OD of pipe	=	6,625	in
Flange nozzle thickness (n)	=	0,432	in
Diameter of hole in reinforcing plate (DR)	=	6 3/4	in
Length if side of reinforcing plate (L)	=	16 1/4	in
Width of reinforcing plate (W)	=	20 1/4	in
Distance, shell to flange face, outside (J)	=	8	in
Distance, shell to flange face, inside (K)	=	6	in
Distance from bottom of tank to center of nozzle	=		
- Reguler, type H	=	11	in
- Low, Type C	=	8 1/8	in

Berdasarkan buku Brownell tabel 12.2, maka akan diperoleh dimensi flange untuk semua nozzle dipilih tipe flange standart type welding neck dengan dimensi :

- Nozzle A = Nozzle pemasukan bahan baku kalsium karbonat
- Nozzle B = Nozzle pemasukan bahan baku asam sulfat
- Nozzle C = Nozzle pengeluaran gypsum
- Nozzle D = Nozzle pengeluaran gas karbondioksida
- Nozzle E = Nozzle pemasukkan air pendingin
- Nozzle F = Nozzle pengeluaran air pendingin
- Nozzle G = Nozzle untuk manhole
- Nozzle H = Nozzle untuk handhole
- NPS = Ukuran pipa nominal, in
- A = Diameter luar flange, in
- T = Ketebalan minimum flange, in
- R = Diameter luar bagian yang menonjol, in

- E = Diameter hubungan atas, in
- K = Diameter hubungan pada titik pengelasan, in
- L = Panjang julukan, in
- B = Diameter dalam flange, in

Nozzel	NPS	A	T	R	E	K	L	B
A.	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
B.	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
C.	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
D.	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
E	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
F	6	11	1	8 1/2	7 4/7	6,63	3 1/2	6,07
G	20	27 1/2	2 5/6	23	22	20	6 5/6	19,3
H	6	11	1	8 1/2	7 4/7	6,63	3 1/2	6,07

F. Sambungan Tutup (Head) Dengan Dinding Reaktor

Bagian tutup reaktor dan bagian shell reaktor dihubungkan secara flange dan bolting sehingga akan mempermudah perbaikan dan perawatan dari reaktor

Dasar perencanaan :

1. Gasket

   Bahan konstruksi = Flange metal, jacketed, asbestos filled, stainless steel

   Gasket factor (m) = 3,75

   Min. design seating stress = 9000 psia

2. Bolting

   Bahan konstruksi = High Alloy Steel SA 193 Grade B8C Type 347

   Tensile strength minimum = 75000 psia

   Allowable stress (f) = 15000 psia

   (Brownell & Young, Fig 12.11 hal 228)

3. Flange

   Bahan konstruksi = High Alloy Steel SA 240 Grade M Type 316

   Tensile strength minimum = 75000 psia

   Allowable stress (f) = 18750 psi

   Type flange = Ring Flange Loose Type

   (Brownell & Young, APP D-4 hal 342)

- Perhitungan Lebar Gasket

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

(Brownell & Young, Pers. 12.2 hal 226)

Keterangan :

do = diameter luar gasket (in)

di = diameter dalam gasket (in)

y = min. design seating stress

m = gasket factor

p = internal pressure

maka

$$\frac{do}{di} = \left(\frac{9000 - 14,696 \times 3,75}{9000 - 14,696 \; (3,75 + 1)} \right)^{1/2}$$

$$\frac{do}{di} = \left(\frac{8.944,890}{8.930,194} \right)^{1/2}$$

$$\frac{do}{di} = 1,001$$

Jika diasumsikan di = do shell, maka

di = do shell = 168 in = 14 ft

sehingga

do = di x 1,001

= 168 x 1,001

= 168,138 in = 14,0115 ft

Lebar gasket minimum (n)

$$n = \frac{do - di}{2}$$

$$= 0,069 \times \frac{16}{16} = \frac{1,105}{16}$$

$$\approx \frac{3}{16} = 0,188 \text{ in}$$

Diameter rata - rata gasket (G) = di + lebar

= 168 + 1/5

= 168,188 in

= 14,016 ft

- Beban Gasket

Wm_2 = H_y = π x b x G x y (Brownell, hal.240 pers. 12.88)

Keterangan : b = lebar efektif gasket (in)

y = yield (ln/in^2)

G = diameter rata-rata gasket

Lebar seating gasket (b_o) $= \frac{n}{2}$ (Brownell, fig 12.12, hal 229)

$= \frac{0,188}{2}$

= 0,094 in

sehingga

Wm_2 = H_y = π x b x G x y

Wm_2 = H_y = 3,14 x 0,094 x 168,188 x 9.000

= 445.591,758 lb

Beban baut karena internal pressure

$$H = \frac{\pi \times G^2 \times P}{}$$

$= \frac{}{4}$

$= \frac{3,14 \quad x \quad 28287,04 \quad x \quad 14,696}{4}$

= 326.329,421 lb (Brownell, pers. 12.89 hal 240)

Beban baut agar tidak bocor (Hp)

Hp = 2 x b x π x G x m x p

= 2 x 0,094 x 3,14 x 168,188 x 3,8 x 14,7

= 5.457,014 lb (Brownell, pers. 12.90 hal 240)

Total berat beban pada kondisi operasi (Wm_1)

Wm_1 = H + Hp

= 331.786,435 lb (Brownell, pers. 12.91 hal 240)

Karena $Wm_1 < Wm_2$ maka yang mengontrol adalah Wm_2

- Perhitungan luas minimum bolting area

$Am_2 = \frac{Wm_2}{f_\alpha}$ (Brownell, pers. 12.93 hal 240)

$= \frac{28.287,035}{15.000}$

= 1,886 in^2

Trial ukuran baut (Brownell, tabel. 10.4 hal 188 dan tabel 12.3, hal 227)

Ukuran baut	=	3/4	in
Root area	=	0,302	in^2
Bolting spacing	=	3	in
Jarak radial minimum (R)	=	1 1/8	in
Jarak dari tepi (E)	=	1 3/16	in

Jumlah baut (N) $= \frac{Am_2}{\text{Root area}}$

$= \frac{1,89 \text{ in}^2}{0,302 \text{ in}^2}$

= 6,2444 buah

≈ 7 buah

Diameter area baut (C)

C = ID shell + 2 (1,4159 x ts + R)

= 167 + 2 (1,4159 x 1/5 + 1 1/8)

= 167 + 2,78096

= 169,781 in

Diameter luar flange (A)

A = OD = Diameter area baut + 2 E

= C + 2 E

= 169,781 + 2 x 1 1/5

= 172,156 in

Evaluasi lebar gasket

A_b aktual = jumlah baut x root area
= 7 x 0,302
= 2,114 in^2

Lebar gasket minimum

$$W = \frac{Ab\ aktual \times f}{2 \times \pi \times G \times Y}$$

$$= \frac{2{,}1140 \times 15.000}{2 \times 3{,}14 \times 168{,}188 \times 9.000}$$

= 0,00334 in

Lebar flange

$$\text{Lebar flange} = \frac{\text{OD flange} - \text{OD vessel}}{2}$$

$$= \frac{172{,}156 - 168}{2}$$

= 2,078 in

Lebar gasket

Lebar gasket = Lebar flange - Lebar baut - E
= 2,078 - 0,302 - 1,188
= 0,588 in

Lebar gasket minimum = 0,00334 in < 0,588 in (memenuhi)

- Perhitungan Moment

Untuk keadaan tanpa tekanan dalam (bolting up)

$$W = \left(\frac{Am + A_b}{2}\right) \times f_a$$

$$= \left(\frac{1{,}89 + 2{,}1140}{2}\right) \times 18.750$$

= 37.498,147 Ib (Brownell, pers. 12.94 hal 242)

Jarak radial dari beban gasket yang bereaksi terhadap bolt circle (h_G)

$$h_G = \frac{1}{2}(C - G)$$

$$= \frac{1}{2}(169{,}781 - 168{,}188)$$

= 0,797 in (Brownell, pers. 12.101 hal 242)

Moment Flange (M_a)

M_a = h_G x W
= 0,797 x 37.498,147
= 29.875,946 lb.in

Untuk keadaan moment pada kondisi operasi :

W = Wm_1
= 331.786,435 lb

Gaya hidrostatik pada daerah dalam flange (H_D)

H_D = 0,79 x B^2 x P

dimana :

B = do shell

p = Tekanan desain

H_D = 0,79 x 28.224,00 x 14,696

= 325.602,225 lb

Jarak jari - jari bolt circle H_D (h_D)

h_D = 0,5 (C - B)

= 0,5 (169,781 - 168)

= 0,890 in

Moment komponen (M_D)

M_D = H_D x h_D

= 325.602,225 x 0,890

= 289.942,676 lb.in

Perbedaan beban berat flange dengan gaya hidrostatis total (H_G)

H_G = W - H = Wm_1 - H

= 331.786,435 - 326.329,421

= 5.457,014 lb

Moment komponen (M_G)

M_G = H_G x h_G

= 5.457,014 x 0,797

= 4.347,773 lb.in

Perbedaan gaya hidrostatis total dengan gaya hidrostatis dalam area flange :

H_T = H - H_D

= 326.329,421 - 325.602,225

= 727,196 lb

Hubungan lever arm (h_T)

hT = 0,5 (h_D + h_G)

= 0,5 (0,890 + 0,797)

= 0,844 in

Moment komponen (M_T)

M_T = H_T x h_T

= 727,196 x 0,844

= 613,467 lb.in

Total moment pada keadaan operasi (Mo)

Mo = M_D - M_G + M_T

= 289.942,676 - 4.347,773 + 613,467

= 286.208,370 lb.in

Karena Ma < Mo, maka M_{max} = Mo, maka M_{max} = M(= 286208 lb.in

- Perhitungan tebal flange

Tf $=$ $\left(\frac{y \times Mmax}{\ }\right)^{0,5}$ (Brownell, pers. 12.85 hal 239)

$$= \left(\frac{\cdot}{f \times B} \right)$$

$$k = \frac{A}{B}$$

Keterangan :

f = stress yang diijinkan untuk bahan flange

B = diameter luar reaktor/shell

A = diameter luar flange

maka

$$k = \frac{A}{B}$$

$$= 1{,}014$$

Dari fig. 12.22 Brownell & Young hal. 238 diperoleh harga y = 95

$$Tf = \left(\frac{95 \times 286208}{18750 \times 168{,}000} \right)^{0,5}$$

$$= 2{,}9380 \text{ in}$$

Jadi digunakan tebal flange = 3 in

Kesimpulan

- Bagian flange

Bahan	=	High alloy steel SA 336 Grade F8m, Type 316
Tebal	=	3 in
ID	=	169,781 in
OD	=	172,156 in
Type flange	=	Ring Flange Loose Type

- Bagian bolting

Bahan	=	High Alloy Steel SA 193 Grade B8C Type
Ukuran	=	3/4 in
Jumlah	=	7 buah
Jarak dari tepi	=	1 1/5 in
Jarak radial minimum	=	1 1/8 in

- Bagian gasket

Bahan	=	Flange metal, jacketed, asbestos filled, steel
Lebar	=	0,188 in

G. Perhitungan Sistem Penyangga Reaktor

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

- Berat shell reaktor
- Berat tutup atas reaktor
- Berat tutup bawah reaktor
- Berat liquid dalam reaktor
- Berat jaket pendingin

- Berat attachment

Perhitungan :

- Berat shell reaktor

W_s = $\pi/4 \left(do^2 - di^2 \right) x\ H\ x\ \rho$

Keterangan : (Hesse, pers. 4-16 hal 92)

W_s = berat shell reaktor, lb

d_o = diameter luar shell

d_i = diameter dalam shell

H = tinggi shell reaktor

ρ = densitas dari bahan konstruksi = 489 lb/ft^3

(Perry, edisi 6 tabel 3-118 hal. 3-95, steel cold drawn)

maka

W_s = $\pi/4 \left(do^2 - di^2 \right) x\ H\ x\ \rho$

$= \frac{3,14}{4} \ (196 - 194) \ 20 \ x \ 489$

= 17.832,161 lb

= 8.087,148 kg

- Berat tutup atas

W_d = A x t x r

A = 6,28 x L x h (Hesse, pers. 4-16 hal. 92)

Keterangan :

W_d = berat tutup atas , lb

A = luas tutup atas , ft^2

t = tebal tutup = 1/5 in = 0,01563 ft

ρ = ρ bahan konstruksi = 489 lb/ft^3

L = crown radius (R) = 144 in = 12 ft

h = tinggi tutup reaktor = 36,711 in = 3,05929 ft

maka luas tutup atas :

A = 6,28 x 12 x 3,059

= 230,548 ft^2

sehingga berat tutup atas :

W_d = 230,548 x 0,0156 x 489

= 1.761,532 lb

= 798,881 kg

- Berat tutup bawah conical

W_d = A x t x ρ

A = $0,785\ (D + m) \sqrt{4h^2 + (D-m)} + 0,78\ d^2$

Keterangan :

t = tebal tutup bawah = 1/5 in = 0,02 ft

ρ = ρ bahan konstruksi = 489 $lb//ft^3$

D = diameter dalam silinder = 167,0 in = 13,9 ft

h = tinggi tutup bawah reaktor = 48,209 in = 4,02 ft
m = flat spot diameter = 1/2 D = 24,104 in = 2,01 ft
maka luas tutup bawah :

$$A = 0,785\ (D + m)\ \sqrt{4h^2 + (D-m)} + 0,78\ d^2$$

$= 260,384\ ft^2$

sehingga berat tutup bawah :

W_d = A x t x ρ
= 260,384 x 0,0156 x 489
= 1.989,494 lb
= 902,265 kg

- Berat liquid dalam reaktor

W_l = m . t

Keterangan
m = berat larutan dalam reaktor = 53.093,474 lb/jam
t = waktu tinggal liquid dalam rektor = 10 menit = 0,17 ja

maka
W_l = m . t
= 8.848,912 lb
= 4.013,112 kg

- Berat jaket pemanas

$$W_{jaket} = \frac{\pi}{4} \times (d_{oj} - d_{ij})^2 \times T_j \times \rho$$

Keterangan
W_{jaket} = berat jaket, lb =
d_{oj} = diameter luar jaket = 40,000 in = 3,33 ft
d_{ij} = diameter dalam jaket = 23,625 in = 1,97 ft
T_j = tinggi jaket = 84,929 in = 7,08 ft
ρ = densitas bahan konstruksi = 489 lb/ft^3

maka berat jaket ;

$$W_{jaket} = \frac{\pi}{4} \times (d_{oj} - d_{ij})^2 \times T_j \times \rho$$

$$= \frac{\pi}{4} \times (3,33 - 1,97)^2 \times 7,08 \times 489$$

= 5.058,855 lb
= 2.294,265 kg

lalu untuk berat pendingin
$V_{pendingin} \times \rho_{pendingin}$ = 12,631 ft^3 x 0,066 lb/ft^3
= 0,835 lb
= 0,379 kg

Jadi untuk berat jaket pemanas
$W_{jaket+pendingin}$ = 2294,265 kg x 0,379 kg
= 868,665 kg

- Berat attachment

  Berat attachment meliputi seluruh perlengkapan sepert nozzle dll.

  W_a = 18% x W_s

  Keterangan :

  W_a = berat attachment, lb

  W_s = berat shell reaktor = 17.832,161 lb = 8.087 kg

  maka berat attachment :

  W_a = 18% x W_s

  = 18% x 17.832,161

  = 3.209,789 lb = 1.455,687 kg

Berat total reaktor = $\sum$ W

= 16.125,758 kg

Untuk faktor keamanan (factor safety) 10% maka berat total :

W total = (18% x $\sum$ W) + $\sum$ W

= 2.902,636 + 16.125,758

= 19.028,394 kg = 41.957,609 lb

H. Perhitungan Kolom Penyangga Reaktor (Leg)

Dasar Perencanaan :

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

Perhitungan :

- Beban tiap kolom (Brownell, pers. 10.76, hal 197)

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

Keterangan :

P = beban tiap kolom, lb

P_W = total beban permukaan karena angin, lb

H = tinggi vessel dari pondasi, ft

L = jarak antara vessel dengan dasar pondasi, ft

n = jumlah support

D_{bc} = diameter anchor bolt circle, ft

$\sum$W = berat total reaktor, lb

Reaktor diletakkan di dalam ruangan sehingga P_w = 0 maka

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

$$= \frac{41.957,609}{4}$$

= 10.489,402 lb

= 4.757,099 kg

- Panjang Penyangga (Leg)

  Direncanakan

Jarak kolom penyangga dari tanah (L) = 5 ft
Tinggi reaktor (H) = 324,541 in = 27,0 ft
maka
Panjang penyangga (Leg) = 1/2 (H + L)
= 1/2 (27,045 + 5)
= 16,023 ft
= 192,270 in

- Trial Ukuran I-beam

Trial ukuran I-beam dengan menggunakan ukuran 5 in ukuran 5 x 3 dengan pemasangan memakai beban eksentrik (terhadap sumbu)
Berdasarkan brownell, APP G-3 hal 355, didapatkan:

Nominal size	=	5	in
Berat	=	10	lb
Area of section (Aγ)	=	2,87	in^2
Depth of beam (h)	=	5	in
Width of flange (b)	=	3	in
I	=	12,1	in^4
Axis (r)	=	2,05	in

Analisa terhadap sumbu Y-Y, dengan :

$$\frac{L}{r} = \frac{192,270}{2,05}$$

$$= 93,7905$$

Untuk L/r < 120 maka memenuhi

f_c = 15000 psi

stress kompresif yang diizinkan (fc)

$$f_c = \frac{18000}{1 + \left[\frac{L^2}{18000 \times r^2}\right]}$$

$$= \frac{18000}{1 + \left[\frac{36967,941}{18000 \times 4,2}\right]}$$

$$= 12.091,061 \text{ psia}$$ (Brownell, hal 201)

fc < 15.000 psi, sehingga memenuh maka *fc* aman = *fc*

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

$$= \frac{10489,40 \text{ lb}}{12091,0615 \text{ psi}}$$

$$= 0,868 \; in^2$$

Karena A yang dibutuhkan lebih kecil dari A yang tersedia maka I-Beam memadai, maka esimpulan I-Beam :

Ukuran	=	5	
Berat	=	10	lb
Area of section (Aγ)	=	2,87	in^2
Depth of beam (h)	=	5	in
Width of flange (b)	=	3	in
I	=	12,1	in^4
Axis (r)	=	2,05	in

I. Perancangan Base Plate

Dasar perencanaan :

- Base plate dengan toleransi panjang sebesar 5% dan toleransi lebar sebesar 2% (Hesse, hal 163)
- Bahan konstruksi base plate adalah besi cor, dimana f_{bp} = 600 lb/in^2

Perhitungan :

- Luas base plate

$$A_{bp} = \frac{P}{f_{bp}}$$

Dimana:

A_{bp} = luas base plate (in^2)

P = beban dari tiap base plate

f_{bp} = stress yang diterima oleh pondasi yang terbuat dari beton

maka,

$$A_{bp} = \frac{P}{f_{bp}} = \frac{10.489,402}{600} = 17,482 \ in^2$$

- Panjang dan lebar base plate

A_{bp} = l x p

dimana:

l = lebar base plate = 2 n + 0,8 b

p = panjang base plate = 2 m + 0,95 h

Dengan I-beam 5 in :

b = 3 in

h = 5 in

Dengan mengasumsikan m = n, maka: (Hesse, hal. 163)

A_{bp} = (2 m + 0,95 h) x (2 n + 0,8 b)

17,482 = [2 m + (0,95 x 5)] x [2 m + (0,8 x 3

17,482 = [2 m + 4,750] x [2 m + 2,4]

17,482 = $4\,m^2$ + 4,8 m + 9,500 m + 11,400

17,482 = $4\,m^2$ + 14,300 m + 11,400

0 = $4\,m^2$ + 14,300 m + -6,082

Dengan menggunakan rumus persamaan kuadrat, didapatkan

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

m_1 = 0,384

m_2 = -3,959

Didapatkan nilai m = n = 0,384 in

sehingga untuk nilai l dan p :

l = 2 n + 0,8 b
= 0,768 + 2,4
= 3,168 in
≈ 4 in

p = 2 m + 0,95 h
= 0,768 + 4,750
= 5,518 in
≈ 6 in

Jadi, luas base plate = P x L
= 24 in^2

- Peninjauan terhadap bearing capacity (*f*)

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

Keterangan :

f = bearing capacity, lb/in^2

P = beban tiap kolom

A = luas base plate

sehingga

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

$$= \frac{10.489,402}{24}$$

= 437,058 lb/in^2 < 600 lb/in^2

(dimensi base plate sudah memenuhi)

- Peninjauan terhadap nilai m dan n

P = 2 m + 0,95 h
6 = 2 m + 0,95 x 5
6 = 2 m + 4,750
2 m = 1,250
m = 0,625

L = 2 n + 0,8 b
4 = 2 n + 0,8 x 3,00
4 = 2 n + 2,4

$2n = 1{,}600$

$n = 0{,}800$

Karena harga n > m, maka tebal base plate dihitung berdasarkan harga n

- Tebal base plate

$t_{bp} = \sqrt{0.00015\ f_{baru} \times n^2}$

Keterangan :

t = tebal base plate, in

f = actual unit pressure yang terjadi pada base plate

maka tebal base plate :

$t_{bp} = \sqrt{0.00015\ f_{baru} \times n^2}$

$= 0{,}20\ in \approx 1\ in$

- Ukuran baut

$P_{baut} = \frac{P}{n}$

$= \frac{10.489{,}40}{7}$

$= 1.498{,}486\ lb$

$A_{baut} = \frac{P_{baut}}{ft}$

dimana :

A_{baut} = luas baut

P_{baut} = beban tiap baut = 1.498,486 lb

ft = stress maksimal tiap baut = 12000 psi

maka luas baut :

$A_{baut} = \frac{P_{baut}}{ft}$

$= \frac{1.498{,}486}{12000}$

$= 0{,}125\ in^2$

$A_{baut} = \frac{1}{4} \times \pi \times db^2$

$0{,}12 = 0{,}785\ d_b^2$

$d_b^2 = 0{,}159$

$d_b = 0{,}399$

$= 0{,}40\ in$

Berdasarkan Brownell, tabel 10.4 hal 188, didapatkan spesifikasi baut dengan ukuran 3/4 in :

Ukuran = 3/4 in

Root area = 0,302 in

Bolt spacing = 3 in

Minimum radial distance = 1 1/8 in
Edge distance = 1 1/5 in
Nut dimension = 1 1/4 in
Maximum fillet radius = 3/8 in

J. Perencanaan Lug dan Gusset

- Berdasarkan Brownell, fig. 10.6, hal 191, diperoleh

Lebar lug (A) = ukuran baut + 9 in
= 0,75 + 9 in
= 10 in

Jarak antar gusset (B) = ukuran baut + 8 in
= 0,75 + 8 in
= 9 in

Lebar gusset (L) = 2 (lebar kolom - 0,5 ukuran baut)
= 2 x [4 - (0,5 x 0,75)]
= 7,250 in

Lebar lug atas (a) = 2 (panjang kolom - ukuran baut)
= 2 x [6 - 0,75)]
= 9,000 in

- Perbandingan tebal base plate (Brownell, hal. 193)

Perbandingan tebal base plate $= \frac{B}{L}$

$= \frac{9 \text{ in}}{7 \text{ in}}$

= 1,21 in

- Berdasarkan Brownell table 10.6 hal 192, digunakan B/L = 1 maka didapat γ1 = 0,57

e = 0,5 x nut dimension
= 0,5 x 1,25
= 0,63 in

- Tebal plate horizontal (lug)

Menentukan maksimum banding sepanjang sumbu radial

$$M_Y = \frac{P}{4\pi}\left[(1+\mu) \times \ln \frac{2L}{\pi e} + (1-\gamma_1) \right]$$

Keterangan (Brownell, pers. 10.38 hal 192)

P = beban tiap baut = 1.498,486 lb
μ = posson's ratio = 0,3 untuk steel
L = panjang horizontal plate bawah = 7,250 in
e = nut dimension = 1,250 in
γ_1 = 0,565

$M_Y = \frac{1.498,486}{4 \times 3,14} [$ 1,3 x In $\frac{2 \times 7,25}{3,14 \times 1,250}$ + (1 -
0,57)

= 119,306 [2,13]

= 254,578 Ib

$T_{hp} = \sqrt{\dfrac{6 \times M_y}{f}}$

= 0,29 in

- Tebal plate vertikal (Gusset)

  Berdasarkan Brownell, fig. 10.6, hal. 191 dan pers 10.47 hal 194

  Tebal gusset minimal = 0,38 x t_{hp}

  = 0,38 x 0,29

  = 0,11 in

- Tinggi gusset (h_g)

  Tinggi gusset (h_g) = A + ukuran baut

  = 10 + 1

  = 11 in

- Tinggi lug

  Tinggi lug = h_g + 2 t_{hp}

  = 11 + 2 x 0,29

  = 11,071 in

  Kesimpulan Dimensi Lug dan Gusset

  - Lug

    Lebar = 9,75 in

    Tebal = 0,29 in

    Tinggi = 11,071 in

  - Gusset

    Lebar = 7,3 in

    Tebal = 0,11 in

    Tinggi = 10,500 in

K. Perhitungan Pondasi

Dasar perencanaan :

Beban total yang harus ditahan pondasi :

- Berat total reaktor
- Berat kolom penyangga
- Berat base plate

Ditentukan

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

Perhitungan :

- Berat total reaktor

  W = 19.028,394 kg = 41.957,609 lb

- Beban yang ditanggung tiap kolom

  W_{bp} = p x l x t x ρ

  Keterangan :

p	=	panjang base plate	=	6	in	=	0,50	ft
l	=	lebar base plate	=	4	in	=	0,33	ft
t	=	tebal base plate	=	1	in	=	0,08	ft
ρ	=	densitas dari bahan konstruksi	=	489	lb/ft^3			

  maka

  W_{bp} = 0,50 x 0,33 x 0,08 x 489

  = 6,792 lb

- Beban tiap penyangga

  W_p = L x A x F x ρ

  keterangan

L	=	tinggi kolom	=	16,023	ft			
A	=	luas kolom I-beam	=	0,868	in^2	=	0,01	ft^2
F	=	faktor koreksi	=	3,4				
ρ	=	densitas dari bahan konstruksi	=	489	lb/ft^3			

  maka

  W_p = 16,023 x 0,01 x 3,4 x 489

  = 160,488 lb

- Beban total

  W_{total} = W + W_{bp} + W_p

  = 42.124,889 lb

- Berat pondasi

  Dianggap hanya ada gaya vertikal dan berat kolom yang bekerja pada pondasi maka :

  Luas atas = 70 x 70 in

  Luas bawah = 80 x 80 in

  Tinggi = 80 in

  ρ_{semen} = 144 lb/ft^3

  Luas permukaan tanah rata - rata :

  A = 80 x 80

  = 6.400 in^2

  Volume pondasi

  V = A x t

  = 6.400 x 80

  = 512.000 in^3

  = 296 ft^3

  Berat pondasi

  W = V x ρ

  = 296 x 144

  = 42.667 lb

= 19.350 kg

- Tekanan tanah

Pondasi didirikan diatas semen sand and gravel

Save bearing minimum = 5 ton/ft^2

Save bearing maksimum = 10 ton/ft^2

Kemampuan tanah menahan tekanan :

$$P = 10\ ton/ft^2 \times \frac{2204{,}62\ lb}{1\ ton} \times \frac{1\ ft^2}{144\ in^2}$$

= 153,099 lb/in^2

Tekanan pada tanah :

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

dimana :

W = berat beban total + berat pondasi

A = luas bawah pondasi

sehingga:

$$P = \frac{42.124{,}89 + 42.667}{6400}$$

= 13,249 lb/in^2 < 153,0988 lb/in^2

Karena tekanan yang diberikan ke tanah lebih kecil daripada kemampuan tanah untuk menahan pondasi, maka pondasi dengan ukuran 70 x 70 in untuk luas atas dan 80 x 80 in untuk luas bawah dengan tinggi pondasi 80 in dapat digunakan.

Kesimpulan Dimensi Reaktor

A. Bagian Silinder (Shell)
- Bahan = High Alloy Steel SA 240 Grade M Type 316
- di = 167 in = 13,917 ft
- do = 168 in = 14,000 ft
- ts = 1/5 in = 0,016 ft
- Ls = 239,621 in

B. Bagian tutup atas
- Bentuk tutup = Standar dished heads
- tha = 1/5 in = 0,02 ft
- ha = 36,711 in = 3,06 ft

C. Bagian tutup bawah
- Bentuk tutup = Conical dengan sudut 120^0
- thb = 1/5 in = 0,02 ft
- hb = 48,209 in = 4,02 ft

Kesimpulan Dimensi Jaket Pendingin

- Bahan konstruksi	=					
- Diameter luar (doj)	=	40	in	=	3,33	ft
- Diameter dalam (dij)	=	23,625	in	=	1,97	ft
- Tebal jaket (tj)	=	3/16	in			
- Tinggi jaket (Lsj)	=	84,929	in	=	7,08	ft

Kesimpulan Dimensi Nozzle

A. Nozzle pemasukan bahan baku $CaCO_3$

Size	=	3	
OD of pipe	=	3,5	in
Flange nozzle thickness (n)	=	0,3	in
Diameter of hole in reinforcing plate (DR)	=	3 5/8	in
Length if 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	=		
- Reguler, type H	=	7	in
- Low, Type C	=	3 1/2	in

B. Nozzle pemasukan asam sulfat

Size	=	3	
OD of pipe	=	3,5	in
Flange nozzle thickness (n)	=	0,3	in
Diameter of hole in reinforcing plate (DR)	=	3 5/8	in
Length if 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	=		
- Reguler, type H	=	7	in
- Low, Type C	=	3 1/2	in

C. Nozzle pengeluaran produk Gypsum

Size	=	3	
OD of pipe	=	3,5	in
Flange nozzle thickness (n)	=	0,3	in
Diameter of hole in reinforcing plate (DR)	=	3 5/8	in
Length if 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	=		

- Reguler, type H	=	7	in
- Low, Type C	=	3 1/2	in
D. Nozzle pengeluaran gas CO_2			
Size	=	3	
OD of pipe	=	3,5	in
Flange nozzle thickness (n)	=	0,3	in
Diameter of hole in reinforcing plate (DR)	=	3 5/8	in
Length if 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	=		
- Reguler, type H	=	7	in
- Low, Type C	=	3 1/2	in
E. Nozzle pemasukan air pendingin			
Size	=	3	
OD of pipe	=	3,5	in
Flange nozzle thickness (n)	=	0,3	in
Diameter of hole in reinforcing plate (DR)	=	3,625	in
Length if side of reinforcing plate (L)	=	10	in
Width of reinforcing plate (W)	=	12,625	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	=		
- Reguler, type H	=	7	in
- Low, Type C	=	3,5	in
F. Nozzle pengeluaran air pendingin			
Size	=	6	
OD of pipe	=	6,625	in
Flange nozzle thickness (n)	=	0,432	in
Diameter of hole in reinforcing plate (DR)	=	6,75	in
Length if side of reinforcing plate (L)	=	16,25	in
Width of reinforcing plate (W)	=	20,25	in
Distance, shell to flange face, outside (J)	=	8	in
Distance, shell to flange face, inside (K)	=	6	in
Distance from bottom of tank to center of nozzle	=		
- Reguler, type H	=	11	in
- Low, Type C	=	8,125	in
G. Nozzle untuk manhole			
Size	=	20	
OD of pipe	=	20	in
Flange nozzle thickness (n)	=	0,5	in

Diameter of hole in reinforcing plate (DR) = 20,125 in
Length if side of reinforcing plate (L) = 43 in
Width of reinforcing plate (W) = 52,5 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 =
- Reguler, type H = 24 in
- Low, Type C = 21,5 in

H. Nozzle untuk handhole
Size = 6
OD of pipe = 6,625 in
Flange nozzle thickness (n) = 0,432 in
Diameter of hole in reinforcing plate (DR) = 6,75 in
Length if side of reinforcing plate (L) = 16,25 in
Width of reinforcing plate (W) = 20,25 in
Distance, shell to flange face, outside (J) = 8 in
Distance, shell to flange face, inside (K) = 6 in
Distance from bottom of tank to center of nozzle =
- Reguler, type H = 11 in
- Low, Type C = 8,125 in

Nozzel	NPS	A	T	R	E	K	L	B
A.	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
B.	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
C.	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
D.	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
E	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
F	6	11	1	8 1/2	7 4/7	6,63	3 1/2	6,07
G	20	27 1/2	2 5/6	23	22	20	6 5/6	19,30
H	6	11	1	8 1/2	7 4/7	6,63	3 1/2	6,07

Kesimpulan Flange
- Bahan konstruksi = High Alloy Steel SA 240 Grade M Type 316
- Tensile strength minimum = 75000 psia
- Allowable stress (f) = 18750 psia
- Type flange = Ring Flange Loose Type
- Tebal flange = 3 in
- Diameter dalam flange = 169,781 in
- Diameter luar flange = 172,156 in

Kesimpulan Bolting
- Bahan konstruksi = High Alloy Stell SA 193 Grade M Type 34
- Tensile strength minimum = 75000 psia

- Ukuran baut = 0,75 in
- Jumlah baut = 7 buah
- Allowable stress (f) = 15000 psia

Kesimpulan Gasket

- Bahan gasket =
- Lebar (L) = 0,588 in
- Gasket faktor (m) = 3,75
- Diameter rata - rata (G) = 168,188 in

Kesimpulan Sistem Penyangga

- Jenis = Kolom I - beam
- Jumlah = 4 buah
- Panjang (L) = 192,270 in
- Ukuran I - beam = 3
- Area of section (Aγ) = 2,87 in^2
- Depth of beam (h) = 5 in
- Width of flange (b) = 3 in
- I = 12,1 in^4
- Axis (r) = 2,05 in

Kesimpulan Base Plate

- Panjang (p) = 6 in
- lebar (l) = 4 in
- Tebal (t) = 1 in
- Ukuran baut = 3/4 in
- Jumlah baut = 7 buah
- Bahan = Cast iron

Kesimpulan Lug

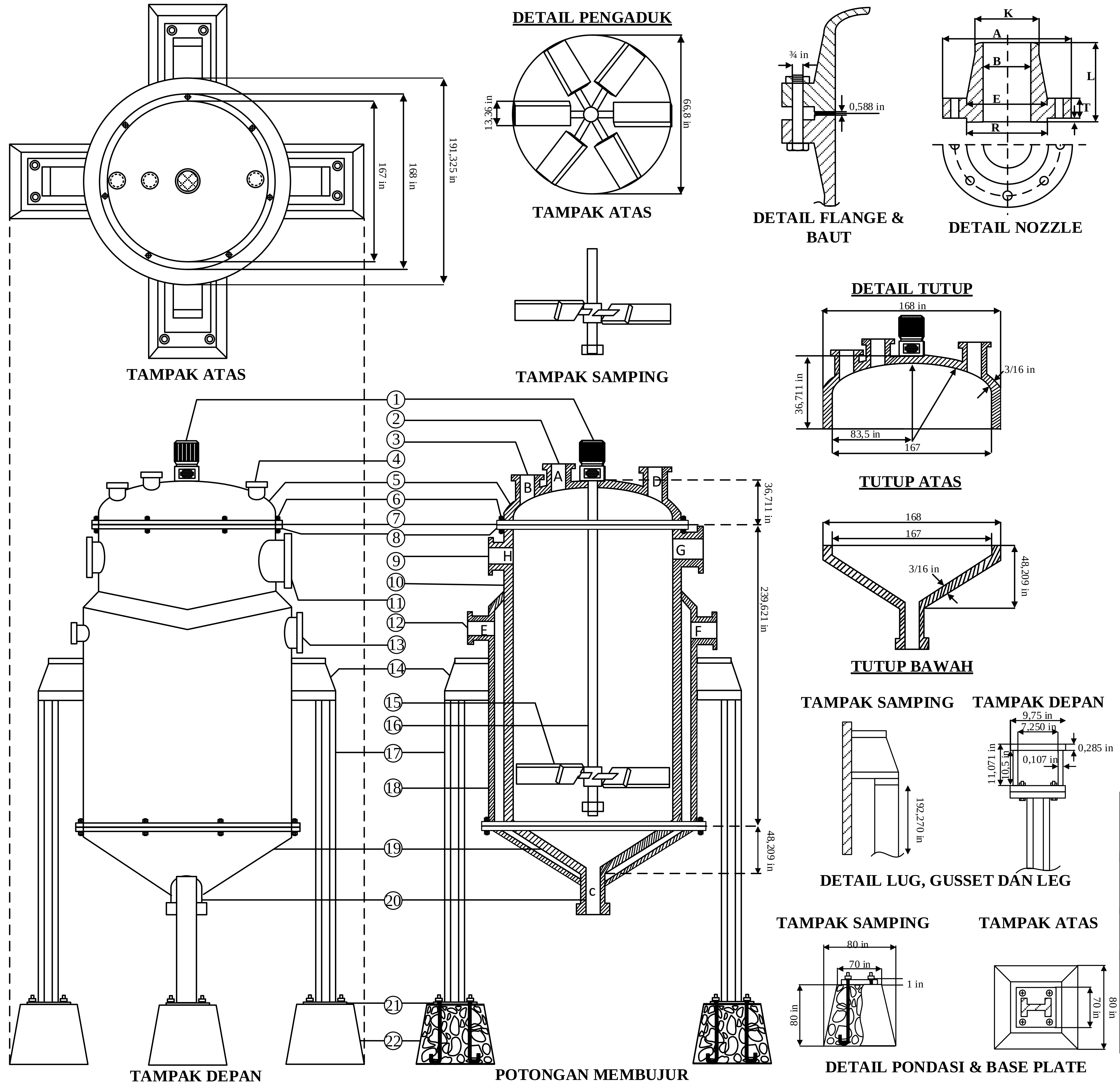
- Lebar = 9,750 in
- Tebal = 0,285 in
- Tinggi = 11,071 in

Kesimpulan Gusset

- Lebar = 7,250 in
- Tebal = 0,107 in
- Tinggi = 10,500 in

Kesimpulan Sistem Pondasi

- Luas atas = 70 x 70 in
- Luas bawah = 80 x 80 in
- Tinggi pondasi = 80 in
- Bahan = Cemen, Sand, and Gravel



Nozzel	NPS	A	T	R	E	K	L	B
A	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
B	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
C	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
D	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
E	3	7 1/2	15/16	5	4 1/4	3,5	2 3/4	3,07
F	6	11	1	8 1/2	7 4/7	6,63	3 1/2	6,07
G	20	27 1/2	2 5/6	23	22	20	6 5/6	19,25
H	6	11	1	8 1/2	7 4/7	6,63	3 1/2	6,07

NO	KETERANGAN	BAHAN
22	PONDASI	CEMENT, SAND AND GRAVEL
21	BASE PLATE	BETON
20	NOZZLE PENGELUARAN PRODUK	HASSA 240 GRADE S TYPE 304
19	TUTUP BAWAH	HASSA 240 GRADE M TYPE 316
18	JAKET PENDINGIN	HASSA 240 GRADE M TYPE 316
17	LEG	HASSA 193 GRADE B8t TYPE 321
16	POROS PENGADUK	HASSA 240 GRADE M TYPE 316
15	PENGADUK	HOT ROLLED STEEL SAE 1020
14	LUG	HASSA 193 GRADE B8t TYPE 321
13	NOZZLE PENGELUARAN PENDINGIN	HASSA 240 GRADE S TYPE 304
12	NOZZLE PEMASUKKAN PENDINGIN	HASSA 240 GRADE S TYPE 304
11	MAN HOLE	HASSA 240 GRADE S TYPE 304
10	SILINDER REAKTOR	HASSA 240 GRADE M TYPE 316
9	HAND HOLE	HASSA 240 GRADE S TYPE 304
8	FLANGE	HASSA 240 GRADE M TYPE 316
7	GASKET	ASBESTOS FILLED
6	BAUT	HASSA 193 GRADE B8 TYPE 304
5	TUTUP ATAS	HASSA 240 GRADE M TYPE 316
4	NOZZLE PENGELUARAN CO_2	HASSA 240 GRADE S TYPE 304
3	NOZZLE PEMASUKKAN H_2SO_4	HASSA 240 GRADE S TYPE 304
2	NOZZLE PEMASUKKAN $CaCO_3$	HASSA 240 GRADE S TYPE 304
1	MOTOR PENGGERAK	HASSA 240 Grade M Type 316

PROGRAM STUDI TEKNIK KIMIA
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PERANCANGAN ALAT UTAMA
REAKTOR

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