BAB X
TUGAS KHUSUS

10.1 Pendahuluan

Industri kimia merupakan industri yang mengolah bahan baku menjadi produk dengan memanfaatkan proses-proses kimia. Gamma Alumina yang diproduksi dari Gibbsite merupakan salah satu produk yang dihasilkan dari proses kimia. Metode yang digunakan dalam pembuatan Gamma Alumina ini adalah dengan proses hidrotermal.

Pada proses ini, gibbsite diumpankan dalam bentuk *Slurry* yang memilki kandungan $Al(OH)_3$ direaksikan dengan HNO_3 untuk menghasilkan produk Al_2O_3 selanjutnya $Al(NO_3)_3$ direaksikan dengan $2H_2O$ untuk menghasilkan produk berupa AlOOH. Produk hasil reaksi ini dilakukan pemurnian agar didapatkan kadar produk mencapai 90% dan dapat dipasarkan.

Reaksi yang terjadi adalah sebagai berikut:

$$Al(OH)_{3\ s)} + 3HNO_{3\ (s)} \rightarrow Al(NO_3)_3 + 3H_2O_{(l)} \quad \Delta H = -\ 1.165,83 \text{ kJ/kmol (1)}$$

$$Al(NO_3)_3 + 3H_2O_{(l)} \rightarrow AlOOH + 3HNO_{3(l)} \quad \Delta H = -\ 1.165,83 \text{ kJ/kmol (1)}$$

$$2AlOOH_{(s)} \rightarrow \gamma\text{-}Al2O3_{(s)} + H_2O_{(l)} \quad \Delta H = -\ 1.165,83 \text{ kJ/kmol (1)}$$

Reaksi yang pertama adalah Aluminium Hidroksida direaksikan dengan Asam nitrat menjadi Aluminium Nitrat yang berlangsung secara eksotermis, sedangkan reaksi kedua yaitu $Al(NO_3)_3$ direaksikan dengan $3H_2O$ menghasilkan AlOOH,dan reaksi ke tiga $2AlOOH_{(s)}$ secara endotermis untuk menghasilkan produk berupa Gamma Alumina.

Perancangan pabrik Gamma Alumina harus mempertimbangkan ketersedian lahan dan bahan baku, pemilihan proses dan peralatan yang digunakan serta pemasaran hasil produksi. Tahapan proses produksi Gamma Alumina meliputi: persiapan bahan baku, reaksi proses, dan pemurnian. Sebelum proses produksi berjalan, langkah awal yang terlebih dahulu dilakukan yaitu, membuat rancangan peralatan proses yang digunakan.

10.2 Ruang Lingkup Rancangan

Perancangan peralatan proses yang digunakan dalam produksi gamma alumina terdiri atas rancangan Mixer 1 (mixer $Al(OH)_3$), alat pencampuran, perancangan alat perpindahan panas dan rancangan peralatan pemisah. *Rotary Kiln* 1 (*rotary kiln* Al_2O_3) merupakan tempat terjadinya reaksi Boehmite dalam proses produksi gamma alumina , alat Pemisahan fluida cair berupa rotary vakum filter, alat perpindahan panas berupa *heater*, serta rancangan dekanter sebagai alat pemisah. Rancangan lengkap peralatan proses dapat dilihat pada sub bab rancangan.

10.3 Rancangan

10.3.1 Rancangan Secara Teoritis

1. Mixer (M-101)

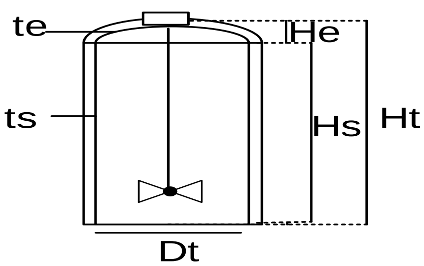
Fungsi : Tempat mencampurkan gibbsite,air dan HNO_3

Jenis : tangki berpengaduk dengan alas dan tutup Hemispherical

Konstruksi : *Carbon Steel SA-285 grade C*

Jumlah : 1 unit

Gambar :



Data:

- Laju alir umpan = 31841,49 kg/jam
- Laju alir molar, F_{AO} =6501,79 kmol/jam
- Densitas umpan = 1,138 kg/m^3 = 82,22031 lb/ft^3
- Viskositas = 0,786 lb/ft.s
- Temperature = 30 ^{0}C
- Tekanan = 1 atm = 14,50 Psi
- Waktu operasi = 1 jam

- **Kapasitas Mixer (Vr)**

Kecepatan laju alir volumetric, Fv $= \frac{laju\ alir\ massa}{densitas}$

$= 27{,}99\ m^3/jam$

Volume mixer dapat dihitung dengan menggunakan persamaan sebagai berikut.

$$\frac{V_R}{F_{AO}} = \frac{\tau}{C_{AO}}$$ (Levenspil Eq 5.11 hal 194)

Vr = Volume mixer

F_{AO} = Laju alir molar umpan

C_{AO} = Konsentrasi umpan

Maka,

C_{AO} $Al(OH)_3$ $= \frac{F_{AO}}{Fv} = 14{,}55\ kmol/m^3$

C_{AO} Fe_2O_3 $= \frac{F_{AO}}{Fv} = 0{,}001\ kmol/m^3$

C_{AO} SiO_2 $= \frac{F_{AO}}{Fv} = 0{,}002\ kmol/m^3$

C_{AO} Na_2O $= \frac{F_{AO}}{Fv} = 0{,}033\ kmol/m^3$

C_{AO} H_2O $= \frac{F_{AO}}{Fv} = 201{,}65\ kmol/m^3$

C_{AO} $(NO_3)_3$ $= \frac{F_{AO}}{Fv} = 14{,}55\ kmol/m^3$

C_{AO} HNO_3 $= \frac{F_{AO}}{Fv} = 1{,}47\ kmol/m^3$

$$\frac{VR}{FAO} = \frac{\tau}{CAO}$$ (Levenspil Eq 5.(11))

C_{AO} $= 217{,}723\ Kmol/m^3$

F_{AO} $= 6501{,}79\ Kmol/jam$

V_c $= \frac{FA0\ x\ t}{CA0}$

V_c $= 29{,}86\ m^3$

Factor keamanan = 20% (Max S. Peters. Tabel 6, hal 37)

V_r $= 37{,}32\ m^3$

$= 1318{,}21\ ft^3$

Evaporators	No	Latent heat of vaporization Temperatures	Flow rate Heat-transfer area	>100:1 >100:1	15
Hammer mills	Yes	Size reduction	Flow rate Power input	60:1 60:1	20
Mixers	No	Mechanism of operation System geometry	Flow rate Power input	>100:1 20:1	20
Nozzle-discharge centrifuges	Yes	Discharge method	Flow rate Power input	10:1 10:1	20 20

(Walas, table 18.5)

Diameter tangki mixer (Dt)

Vr = Vs +Ve

$= \frac{\pi}{4} x\, Dt^3 + \frac{\pi}{12} x\, Dt^3$

$= \frac{4\pi}{12} x\, Dt^3$

= 35,66

Dt = $\sqrt[3]{\frac{12Vr}{4\pi}}$ = 1259,43

Vs = $\frac{\pi}{4} x\, Dt^3$ = 27,996 m^3 = 91,82 ft = 1102,21 in

Ve = $0.1309D^3$ = 27,13834

Dt (ID)= 11ft

= 3,29 m

= 129,591 in

- **Tinggi tangki Mixer (Hr)**

Tinggi silinder (Hs) = 1,5Dt

Hs = 10,79 ft = 3,29 m = 129,59 in

Tinggi head (Hd) = 1/2Dt

Hd = 5,40 ft = 1,64 m = 32,39 in

Tangki direncanakan diletakkan diatas kaki penyangga yang terbuat dari besi dengan tinggi 2 m.

Hr = Hs + (2 x Hd) + (tinggi kaki – Hd)

= 6,93 m = 26,88 ft = 322,63 in

- **Tinggi Cairan Dalam Mixer (Hc)**

Hc $= \frac{Vc}{Vr} \times Hr$ = 5,54 m = 218,50 in

- **Tekanan Cairan Dalam Mixer (Pc)**

Pc = ρ x g x Hc

Pc = 61870,38 kg/m.s^2 = 0,55 atm = 0,772 bar = 8,18 Psi

- **Tekanan Desain (Pd)**

Pd = Pop + Pc = 1,56 Bar = 22,68 Psi

- **Tebal Dinding Mixer (Td), Tebal Tutup Ellipsoidal (Te)**

Td $= \frac{PR}{SE - 0,6P} + C$ (Walas, tabel 18.3)

Tekanan desain (Pd) = 22,68 Psi

Diameter tangki (Dt) = 129,59 in

Jari-jari tangki (r) = 64,79 in

Allowable stress (S) = 13700 Psi (Peter, tabel 4 hal 538)

Effisiensi pengelasan = 0,85 (Peter, tabel 4 hal 538)

Factor korosi yang diizinkan (C) = 0,125 in/tahun (Perrys, tabel 23-2)

Lama tahun yang digunakan = 10 tahun

Td $= \frac{1470,01}{23290,00+265,544}$ 0,125 x 10 tahun

Td = 1,31 in = 33,35 mm

OD = ID + 2.TD = 132,21 in

Joint efficiencies	Recommended stress values: Metal	Temp., °F	S, psi
For double-welded butt joints	Carbon steel	-20 to 650	13,700
if fully radiographed = 1 .O	(SA-285, Cr. C)	750	12,000
if spot examined = 0.85		850	8,300
if not radiographed = 0.70	Low-alloy steel	-20 to 800	13,700
In general, for spot examined	for resistance to	950	11,000
if electric resistance weld = 0.85	H_2 and H_2S	1050	5,000
if lap welded = 0.80	(SA-387, Gr.12C1.1)	1200	1,000
if single-butt welded = 0.60	High-tensile steel	-20 to 750	20,000
	for heavy-wall	850	16,800
	vessels	950	10,000
	(SA-302, Gr.B)	1000	6,200
	High-alloy steel for cladding and corrosion resistance		
	Stainless 304	-20	18,700
		650	11,200
		800	10,500
	(SA-240)	1000	9,700
	Stainless 316	-20	18,700
	(SA-240)	650	11,500
		800	11,000
		1000	10,600
	Nonferrous metals		
	Copper	100	6,700
	(SB-11)	400	3,000
	Aluminum	100	2,300
	(SB-209, 1100-0)	400	1,000

See the latest ASME Boiler and Pressure Vessel Code for further details.

Td $= \frac{36{,}34 \text{ Psi} \times 135{,}82 \text{ in}}{13700\ Psi \times 0{,}85 - 0{,}6 \times 36{,}34\ Psi}$ x 0,125 in/tahun x 10 tahun

= 1,46 in = 37,12 mm

Thead $= \frac{PDt}{2SE - 0{,}2P} + C$ (Walas, tabel 18.4)

Th $= \frac{1470{,}01}{23290{,}000} + 0{,}125 \frac{in}{tahun} \times 10\ tahun$

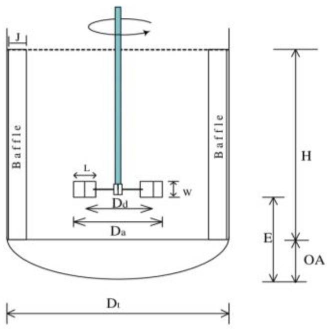
= 1,31 in = 107,23094 mm

TABLE 18.3. Formulas for Design of Vessels under Internal Pressure[a]

Item	Thickness t(in.)	Pressure P(psi)	Stress S(psi)	Notes
Cylindrical shell	$\frac{PR}{SE - 0.6P}$	$\frac{SEt}{R + 0.6t}$	$\frac{P(R + 0.6t)}{t}$	$t \le 0.25D$, $P \le 0.385SE$
Flat flanged head (a)	$D\sqrt{0.3P/S}$	$t^2S/0.3D^2$	$0.3D^2P/t^2$	
Torispherical head (b)	$\frac{0.885PL}{SE - 0.1P}$	$\frac{SEt}{0.885L + 0.1t}$	$\frac{P(0.885L + 0.1t)}{t}$	$r/L = 0.06$, $L \le D + 2t$
Torispherical head (b)	$\frac{PLM}{2SE - 0.2P}$	$\frac{2SEt}{LM + 0.2t}$	$\frac{P(LM + 0.2t)}{2t}$	$M = \frac{3 + (L/r)^{1/2}}{4}$
Ellipsoidal head (c)	$\frac{PD}{2SE - 0.2P}$	$\frac{2SEt}{D + 0.2t}$	$\frac{P(D + 0.2t)}{2t}$	$h/D = 4$
Ellipsoidal head (c)	$\frac{PDK}{2SE - 0.2P}$	$\frac{2SEt}{DK + 0.2t}$	$\frac{P(DK + 0.2t)}{2Et}$	$K = [2 + (D/2h)^2]/6$, $2 \le D/h \le 6$
Hemispherical head (d) or shell	$\frac{PR}{2SE - 0.2P}$	$\frac{2SEt}{R + 0.2t}$	$\frac{P(R + 0.2t)}{2t}$	$t \le 0.178D$, $P \le 0.685SE$
Toriconical head (e)	$\frac{PD}{2(SE - 0.6P)\cos\alpha}$	$\frac{2SEt\cos\alpha}{D + 1.2t\cos\alpha}$	$\frac{P(D + 1.2t\cos\alpha)}{2t\cos\alpha}$	$\alpha \le 30°$

[a] Nomenclature: D = diameter (in.), E = joint efficiency (0.6–1.0), L = crown radius (in.), P = pressure (psig), h = inside depth of ellipsoidal head (in.), r = knuckle radius (in.), R = radius (in.), S = allowable stress (psi), t = shell or head thickness (in.).
Note: Letters in parentheses in the first column refer to Figure 18.16.

- **Desain Pengaduk**



Viskositas = 0,231 cP

Jenis pengaduk = propeller 3 blade

a. The three-bladed mixing propeller is modelled on the marine propeller but has a pitch selected for maximum turbulence. They are used at relatively high speeds (up to 1800 rpm) with low viscosity fluids, up to about 4000 cP. Many versions are available: with cutout or perforated blades for shredding and breaking up lumps, with sawtooth edges as on Figure 10.2(g) for cutting and tearing action, and with other than three blades. The stabilizing ring shown in the illustration sometimes is included to minimize shaft flutter and vibration particularly at low liquid levels.

b. The turbine with flat vertical blades extending to the shaft is suited to the vast majority of mixing duties up to 100,000 cP or so at high pumping capacity. The simple geometry of this design and of the turbines of Figures 10.2(c) and (d) has inspired extensive testing so that prediction of their performance is on a more rational basis than that of any other kind of impeller.

c. The horizontal plate to which the impeller blades of this turbine are attached has a stabilizing effect. Backward curved blades may be used for the same reason as for type e.

Diameter pengaduk (d)	$= \frac{Dt}{3}$	(Mc.cabe, hal 243)
	= 1,09 m = 33,35 mm	
Jarak pengaduk dari dasar tangki (E)	$= \frac{d}{3}$ = 0,36 m = 0,78 cp	
Tinggi pengaduk (H)	= (Hs + 2 x He) – E	
	= 6,21 m	
Jarak baffle dari dasar tangki	= ½ x d = 0,54 m	
		(Walas,,hal 288)
Diameter penyangga pengaduk (Dd)	= 2/3 x d	(Geankoplish, 144)
	= 0,73 m	
Diameter batang pengaduk	= 1/8 x Dd = 0,09 m	
Panjang daun pengaduk (L)	$= \frac{d}{4}$ = 0,27 m = 0,96 ft	
Lebar daun pengaduk (W)	$= \frac{d}{5}$ = 0,21 m = 0,71 ft	
Lebar baffle (J)	$= \frac{Dt}{12}$ = 0,27 m = 0,89 ft	
Jarak baffle dari permukaan	= 1/6 x lebar baffle	
	= 0,04 m (Walas,,hal 288)	
Kebutuhan pengaduk (n)	$= \frac{\text{WELH}}{ID}$	(Rase, pers 8.9)
SPGR	$= \frac{\rho\ zat}{\rho\ referensi}$ = 1,28085	

WELH = water Equivalent Liquid Hight

WELH = Hc x SPGR =12,84124738

Kebutuhan pengaduk (n) = 2 buah

Jarak antar pengaduk $= \frac{Hc}{n} = 2,89$ m

- **Kecepatan Putar Pengaduk (N)**

$$\frac{N \times d}{\left(\frac{\sigma g_c}{\rho}\right)^{0.25}} = 1,22 + 1,25 \left(\frac{D_t}{d}\right)$$

(Rober Treybal-Mass Transfer Operations)

Dimana,

σ = 72,75 dyn/cm = 0,0050 lbf/ft

gc = 32,2 ft/s^2

$$N = \frac{\left(1,22 + 1,25\left(\frac{Dt}{d}\right)\right) x \left(\frac{\sigma g_c}{\rho}\right)^{0.25}}{d}$$

$$= \frac{\left(1,22+1,25 \times \left(\frac{Dt}{d}\right)\right) \times \left(\frac{\sigma gc}{\rho}\right) 0,25}{d} = 0,29 \text{ rps}$$

- **Daya Pengadukan**

$$N_{Re} = \frac{\rho \times N \times d^2}{\mu}$$

(Mc.Cabe & Smith - Unit Operations Of Chemical Engineering 5th,Pers 9.17)

N_{Re} = 436521,007

Karena $N_{Re} > 10.000$ maka,

$$P = \frac{K_T N^3 d^5 \rho}{g_c}$$

K_T = 0,95

TABLE 9.3
Values of constants K_L and K_T in Eqs. (9.21) and (9.23) for baffled tanks having four baffles at tank wall, with width equal to 10 percent of the tank diameter

Type of impeller	K_L	K_T
Propeller, three blades		
Pitch 1.0[40]	41	0.32
Pitch 1.5[35]	55	0.87
Turbine		
Six-blade disk[35] (S_3 = 0.25, S_4 = 0.2)	65	5.75
Six curved blades[40] (S_4 = 0.2)	70	4.80
Six pitched blades[39] (45°, S_4 = 0.2)	—	1.63
Four pitched blades[35] (45°, S_4 = 0.2)	44.5	1.27
Flat paddle, two blades[40] (S_4 = 0.2)	36.5	1.70
Anchor[35]	300	0.35

P = 84,009316 lb.ft/s = 0,95 Hp

Effisiensi motor $= \frac{daya}{kapasitas} = \frac{0,95}{0,8} = 1,193$ Hp

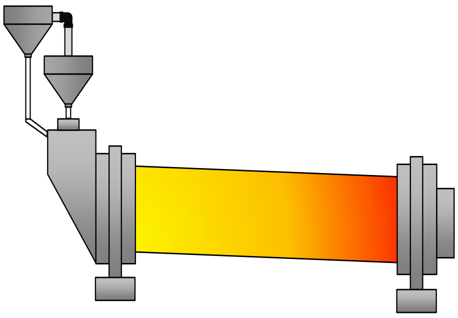
2. Rotary Kiln (RK-31701)

Fungsi : Untuk mengkalsinasi kaolin menjadi metakaolin

Bahan konstruksi : *Carbon Steel* (SA-285 *Grade* A)

Jumlah : 1 Unit

Gambar :



Data :

- Jumlah umpan : 35.627,59 kg/batch
- Tekanan : 1 atm
- Temperatur : 540 ^{o}C
- Densitas : 2200 kg/m^3

Kapasitas *over design* 10 %, maka :

= 35.627,59 kg/*batch* x 1,1

= 39.190,4 kg/*batch*

- **Data desain :**

Dari **Tabel 12-20**, hal. 12-M&UY 59, *Perry's ed.7th*, digunakan *Rotary Kiln* untuk $Al_2Si_2O_5(OH)_4$ / Kaolin (batu kapur/*limestone*) dengan spesifikasi :

- Kapasitas = 35.627,6 ton/batch
- Diameter (D) = 7 ft = 2,28 m
- Panjang (L) = 125 ft = 28,1 m
- Power (P) = 20-30 Hp
- Jumlah unit = 1 unit

- Menentukan Koefiesien Perpindahan Panas Volumetrik

$$\text{Ua} = \frac{0{,}5\ x\ G'G^{0{,}67}}{D}$$ (Mc-Cabe 1999, Pers. 25-28)

Keterangan,

Ua = Koefisien perpindahan panas volumetrik, $\frac{\text{J}}{\text{m}^2\ \text{s K}}$

G'$_G$ = Kecepatan superficial udara, $\frac{\text{kg}}{\text{sm}^2} = 369$ lb/jam.ft^2

D = Diameter Kiln (ft)

Maka,

$$\text{Ua} = \frac{0{,}5\ x\ 369^{0{,}67}}{7{,}5\ \text{ft}}$$

$$\text{Ua} = 3{,}49797\ \frac{\text{BTU}}{\text{ft}^3\ \text{jam}\ ^\text{o}\text{F}}$$

- Menentukan luas penampang *Rotary Kiln*

$$S = \frac{\pi}{4}\ x\ \text{D}^2$$

$$S = \frac{3{,}14}{4}\ x\ 5^2$$

= 44,15 ft = 13,45 m

- Menentukan Tekanan Desain

Asumsi:

a) Tekanan ke arah dinding *kiln* diabaikan karena material termasuk *free flowing* sehingga pada proses pengeluaran bahan tidak menempel pada dinding *kiln*.

b) Tekanan di dalam kiln hanya terjadi karena akibat gaya gravitasi yaitu berupa tekanan hidrostatik saja.

P_{design} = $P_{operasi}$ + $P_{hidrostatik}$

$P_{hidrostatik}$ = ρ x g x h

Keterangan:

ρ = *Bulk density material* (kg/m^3)

g = Tetapan gravitasi (m/s^2)

h = Diameter *kiln* (m)

$P_{hidrostatik}$ = $3950\ \frac{kg}{m^3}\ x\ 9{,}8\ \frac{kg}{m^2}\ x\ 2{,}28$ m

= 88.491,1 kg/m s^2 = 0,3 atm

P_{design} = 1 atm + 0,3 atm

= 1,3 atm (BELUM)

- Menentukan putaran *Rotary Kiln* (N)

$$N = \frac{Vp}{\pi \ x \ D}$$

Dimana :

N = Putaran *Rotary Kiln*, (rpm)

Vp = Kecepatan *peripheral*, (ft/menit)

= 75 ft/menit, (Vp = 60-75 ft/menit, hal.12-57, Perry’s ed.7th)

D = Diameter *inside Rotary Kiln*, (ft) = 5 ft

$$N = \frac{75}{3{,}14 \ x \ 7{,}5 \text{ ft}}$$

= 3,18 rpm

- Menentukan daya *Rotary kiln*

Berdasarkan Perry's 7th, jumlah total daya untuk fan, penggerak dryer dan conveyor umpan maupun produk berkisar antara 0,5 D^2 - 1,0 D^2 (kW). Pada perhitungan ini diambil total daya sebesar 0,5 D^2 sehingga :

P = 0,5 x $(7{,}5)^2$ ft

= 28,12 kW (37,71 hp)

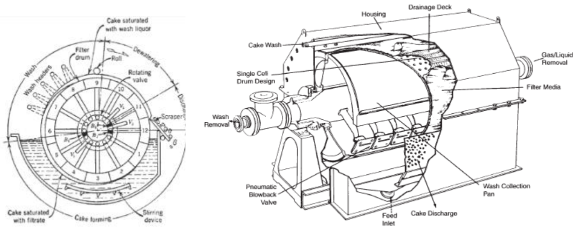
3. Rotary Vakum Filter (RVF-31101)

Fungsi : memisahkan partikel di dalam umpan

Bahan konstruksi : *Stainless Steel* (SA-240), Grade 304 18 Cr-8Ni

Jumlah : 1

Gambar :



Data:

Laju alir massa : 346.470,3166 kg/jam

Padatan : 24.508,1518 kg/jam

ρ padatan : 9.028,62 m^3/jam

Laju alir filtrat : 90.723,17 kg/m^2 jam

ρ filtrat : 90.723,17 m^3/jam

Rate volume padatan = $\frac{24.508,1518\ kg/jam}{9.028,62\ kg/m3}$

= 2,714 m^3/jam

Rate volume liquid = $\frac{90.723,17\ kg/jam}{90.723,17\ kg/m3}$

= 1 m^3/jam

Rate volume slurry = (2,714 + 1) = 3,714 m^3/jam

Cx = konsentrasi padatan = $\frac{2,714\ m3/jam}{3,714\ m3/jam}$ = 0,7307 m^3/jam

Cs = $\frac{\rho filtrat.Cx}{1-Cx}$ = $\frac{90.723,17\ x\ 0,7307}{1-0,7307}$ = 66.298,3401 kg solid/m^3filtrat

Diketahui:

Putaran rotary vakum filter (tc) = 250 s

$\frac{V}{tc}$= $\frac{1\ m3/jam}{250\ m3/jam}$ = 0,004 m^3/s filtrat

Fraksi drum yang tercelup dalam slurry = 33%

ΔPdianggap = 90 kpa = $9x10^4$ Pa

α = $(4,37.10^9).(90.10^3)^{0,3}$ = $1,3389.10^{11}$ m/kg

μ campuran = $1,3639x10^{-3}$ kg/m.s

1. Menghitung Luas Silinder

Untuk menghitung luas silinder substitusi ke persamaan 14.2-24 (Geankoplis, 1993), dimana:

$$\frac{V}{A.tc} = \left(\frac{2.f.(\Delta P)}{tc.\mu.\alpha.Cs}\right)^{1/2}$$

$$\frac{0,004\ m3/s\ filtrat}{A} = \left(\frac{2\ x\ 0,33\ x\ (9x104)}{250\ x\ 1,3639.10-3\ x\ 1,3389.1011\ x\ 66.298,34}\right)^{1/2}$$

A= 400.179.268,3 m^2

Karena luas permukaan silinder (rotary vakum filter) besar maka alat rotary vakum filter dibuat menjadi 3.

A= 400.179.268,3 m^2/ 3

= 133.393.089,4 m^2 = 1.435.829.875 ft^2

2. Diameter silinder

L= 2D

A= π.D.L

A= π.2.D^2

90,12 = 2 x 3,14 x D^2

D = 4.608,78 m

Maka lebar silinder, L= 2D = 2 x 4.608,78 m = 9.217,57 m

3. Daya Motor , Hp

Untuk mengetahui daya motor rotary vakum filter dapat dihitung dari persamaan berikut:

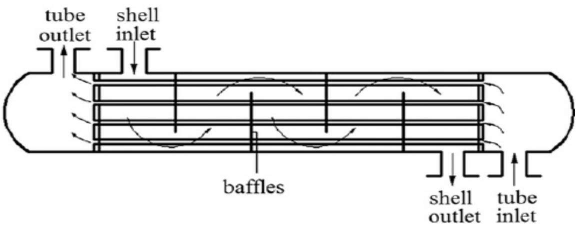
HP = 0,005 hp/ft^2 x A

= 0,005 hp/ft^2 x 1.435.829.875 ft^2

= 17.179.149,62 HP

4. Heater (30-100)^oC (H-10701)

Fungsi	: Memanaskan slurry Gibbsite sebelum memasuki reaktor
Tipe	: *Sheel and Tube Heat Exchanger*
Jumlah	: 1 unit
Bahan Kontruksi	: *Duplex Stainless Steel*
Gambar	:



Data:

Fluida panas	: Steam
Laju alir massa masuk	: 16.811,16 kg/jam = 37.068,61 lb/jam
Temperatur masuk (T1)	: 200^0C = 392 ^0F
Temperatur keluar (T2)	: 66,24 ^0C = 151,24 ^0F
Fluida dingin	: *Slurry* Gibbsite

Laju alir massa masuk : 191.048,95 kg/jam = 421.262,95 lb/jam

Temperatur masuk (T1) : 30 ^{0}C = 86 ^{0}F

Temperatur keluar (T2) : 100 ^{0}C = 212 ^{0}F

- **LMTD (*Log Mean Temperature Difference*)**

Fluida Panas (F)	Temperatur	Fluida Dingin (F)	Selisih	
392	Tinggi	212	180	ΔT2
151,24	Rendah	86	65,24	ΔT1

T_{avg} = ½ (T_1 + T_2) = ½ (392 + 151,24) ^{o}F = 543,24^{o}F

t_{avg} = ½ (t_1 + t_2) = ½ (212 + 86) ^{o}F = 298 ^{o}F

$$LMTD = (\Delta T2 - \Delta T1) / \ln(\frac{\Delta T2}{\Delta T1})$$

LMTD = 113,08 ^{0}F

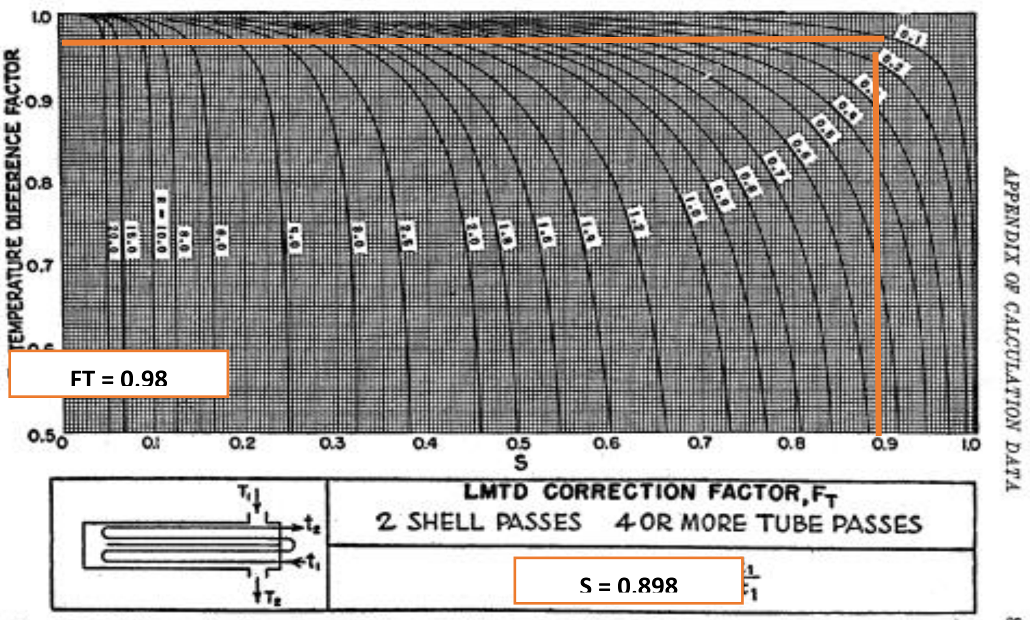


Fig. 19. LMTD correction factors for 2-4 exchangers. (*Standards of Tubular Exchanger Manufacturers Association* 2d ed., *New York*, 1949.)

Faktor koreksi LMTD

$$R = \frac{T1 - T2}{t2 - t1}$$ = 0,1062

$$S = \frac{t2 - t1}{T1 - t1}$$ = 0,898

$$LMTD = (\Delta T2 - \Delta T1) / \ln(\frac{\Delta T2}{\Delta T1})$$

Maka dari gambar 21 D.K. QERN didapatkam faktor koreksi adalah sebagai berikut:

$ft =$ 0,98

$$\Delta T_{LMTD} = ft x LMTD$$ = 30,49 ^{0}F

- **Menentukan luas area perpindahan panas (A)**

$$A = \frac{Q}{U_d x \Delta T_{LMTD}}$$

Dari tabel 8 D.Q. KERN maka didapatkan koefisien perpindahan panas sebesar:

Hot fluid	Cold fluid	Overall U_D
Steam	Water	200–700§
Steam	Methanol	200–700§
Steam	Ammonia	200–700§
Steam	Aqueous solutions:	
Steam	Less than 2.0 cp	200–700
Steam	More than 2.0 cp	100–500§
Steam	Light organics	100–200
Steam	Medium organics	50–100
Steam	Heavy organics	6–60
Steam	Gases	5–50¶

Ud = 700 Btu/jam.ft^2.^{0}F

Q = 39.467.567,94 kj/jam = 34.883.180,54 Btu/jam

A = 495,16 ft^2

Nilai A > 200 ft^2 maka tipe heat excanger yang digunakan adalah Shell and Tube. (DQ Kern Hal - 103)

- **Spesifikasi Shell and Tube**

HE dirancang dengan menggunakan tube 0,75 in dengan 20 ft, maka dari tabel 10 D.Q.KERN diperoleh data sebagai berikut:

OD (in)	A" (ft^2)	BWG	L (ft)
1	0,2618	18	20

- **Menentukan Jumlah Tube**

$$Nt = \frac{A}{Lxa''}$$

Nt = 94,56 = 104 buah

Dari tabel 9 D.Q.KERN, untuk jumlah tube didapatkan spesifikasi perangcangan HE sebagai berikut:

842 PROCESS HEA

TABLE 9. TUBE-SHEET LAYOUT
Triangul

¾ in. OD tubes on $1\frac{5}{16}$-in. triangular pitch					
Shell ID, in.	1-P	2-P	4-P	6-P	8-P
8	36	32	26	24	18
10	62	56	47	42	36
12	109	98	86	82	78
13¼	127	114	96	90	86
15¼	170	160	140	136	128
17¼	239	224	194	188	178
19¼	301	282	252	244	234
21¼	361	342	314	306	290
23¼	442	420	386	378	364
25	532	506	468	446	434
27	637	602	550	536	524
29	721	692	640	620	594
31	847	822	766	722	720
33	974	938	878	852	826
35	1102	1068	1004	988	958
37	1240	1200	1144	1104	1072
39	1377	1330	1258	1248	1212

Shell side		***Tube side (Tabel.10 DQ kern)***	
Diameter dalam (ID)	17 1/4	Diameter dalam (ID) in	0,902
Baffle space (B)=0,4xID	3 4/9	Diameter luar (OD) in	1
Passes (n)	2	BWG	18
		Pitch (Pt)	1,25
		Passes (n)	6
		Panjang (ft)	20
		Panjang (m)	6,10
		Jumlah Tube (N)	104

Shell: Fluida Panas	***tube*: Fluida Dingin**
• ***Flow area*** B = 3 4/9 in Clearence (C') = Pt – OD = 1,25 – 1 = 0,25 in Flow area, $a_s = ID \times C'B/144P_T$, ft² Flow area ($a_s$) = 0,0826 ft² • ***Mass velocity*** $G_s = \frac{W}{a_a}$ $= \frac{37.068 \text{ lb/jam}}{0{,}082\ ft^2}$	• ***Flow Area*** a' = 0,639 in² $a_t = N_t a'_t/144n$, ft² = 0,0769 ft² • ***Mass velocity*** $G_t = \frac{w}{a'}$ $= \frac{421.262{,}9 lb/jam}{0{,}076\ ft^2}$ = 5.476.874,69 lb/jam ft² • **Bilangan Reynold** tav = 149 ^{0}F

= 448.467,137 lb/jam ft^2

- **Bilangan Reynold**

Tav = 316,71^{0}F

μ = 0,015 cP *(Fig 15 Kern)*

= 0,0363 lb/ft.jam

De = 0,0458 ft

$N_{Re} = \frac{De.G_a}{\mu}$

$= \frac{0{,}0458 \text{ ft } x 192.090{,}38 \text{ lb/ft}^2 \text{ jam}}{0{,}0363 \text{ lb/ft.jam}}$

= 250.114,12

- **jH**

jH = 180 *(Fig 24 Kern)*

c = 0,45 Btu/lb^{o}F *(Fig 3 Kern)*

k = 0,0154 Btu/jam ft^2 (^{o}F/ft)

(Tabel 5 Kern)

$\left(\frac{c.\mu}{k}\right)^{1/3}$ = 2,77

- **ho**

$$ho = jHx \frac{k}{De} x \frac{c\mu^{1/3}}{k} x \frac{\mu^{0,14}}{\mu w}$$

ho/Φs = 92,84 Btu/hr.ft^2(◦F)

tw = $\frac{tc + \frac{ho}{\phi s}}{\frac{ho}{\phi s} + \frac{hio}{\phi t}} \times (Tav - tav)$

= 18,33 ^{o}F

μw = 0,46 cP = 1,1132 lb/ft.jam

Φs = $\left(\frac{\mu s}{\mu w}\right)^{0,14}$ = 0,94

ho = $\frac{ho}{\phi s} \times \phi s$ = 87,44 btu/ ft^2.hr

μ = 0,39 cP *(Fig 15 Kern)*

= 0,96 lb/ft.jam

D = 0,0752 ft

$N_{Re} = \frac{D.G_P}{\mu}$

$= \frac{0{,}0752 \text{ ft } x \ 5.476.874{,}69 \text{ lb/ft}^2 \text{ jam}}{0{,}9621 \text{ lb/ft.jam}}$

= 427.854,75

- **jH**

jH = 650 *(Fig 28 Kern)*

c = 0,31 Btu/lb ^{o}F *(Fig 2 Kern)*

k = 0,158 Btu/jam ft^2 (^{o}F/ft)

(Tabel 4 Kern)

$\left(\frac{c.\mu}{k}\right)^{1/3}$ = 1,235

- **ho**

$$hi = jHx \frac{k}{De} x \frac{c\mu^{1/3}}{k} x \frac{\mu^{0,14}}{\mu w}$$

hi/Φt = 1.689,89 Btu/hr.ft2(◦F)

$\frac{hio}{\Phi t} = \frac{hi}{\Phi t} \times \frac{ID}{OD}$ = 857,85 Btu/hr.ft^2(◦F)

μw = 0,1 cP = 0,962 lb/ft.jam

Φt = $\left(\frac{\mu t}{\mu w}\right)^{0,14}$ = 1

- **Koreksi hi**

hio = $\frac{hio}{\phi t} \times \phi t$ = 1.524,28 btu/ ft^2.hr

- ***Clean overall coefficient*** **(Uc)**

Uc = $\frac{ho \times hio}{ho + hio}$ = 82,7004 btu/ ft^2.hr. ◦F

- ***Desain overall coefficient*** **(Ud)**

$Rd = \frac{Uc - Ud}{Uc x Ud}$ = 0,0105

- ***Pressure Drop***

D_e = 0,0825 ft

Re_s = 50.962,17

f = 0,0001 ft

s = 1 *(Tabel 6 Kern)*

Gs = 448.467,13 lb/jam ft^2

N + 1 = 12L/B = 69,75

Ds = ID/12 = 14/9 = 1,55

$$\Delta P_s = \frac{f G_s^2 D_s (N+1)}{5.22 \times 10^{10} D_e s \phi_t} \quad \text{[Eq. (7.44)]}$$

= 0,467 Psi

Untuk N_{Ret} = 427.854,75

f = 0,00014 ft

s = 2,03 *(Tabel 6 Kern)*

ρ = 62,5 x 2,03 = 126,87 lb/ft^3

$$\Delta P_t = \frac{f G_t^2 L n}{5.22 \times 10^{10} D s \phi_t} \quad \text{[Eq. (7.45)]}$$

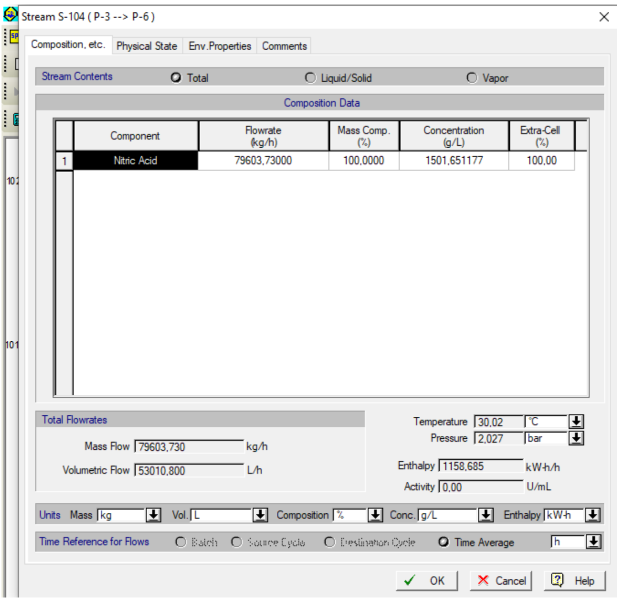
= 5,24 psi

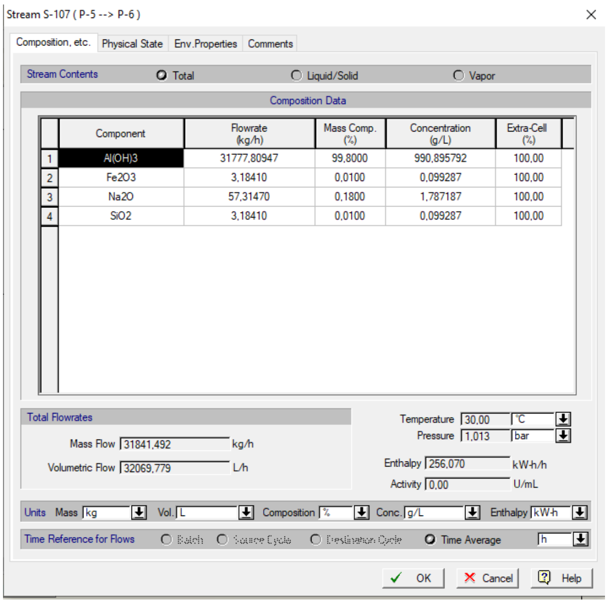
10.3.2 Rancangan Secara Simulasi Super Pro

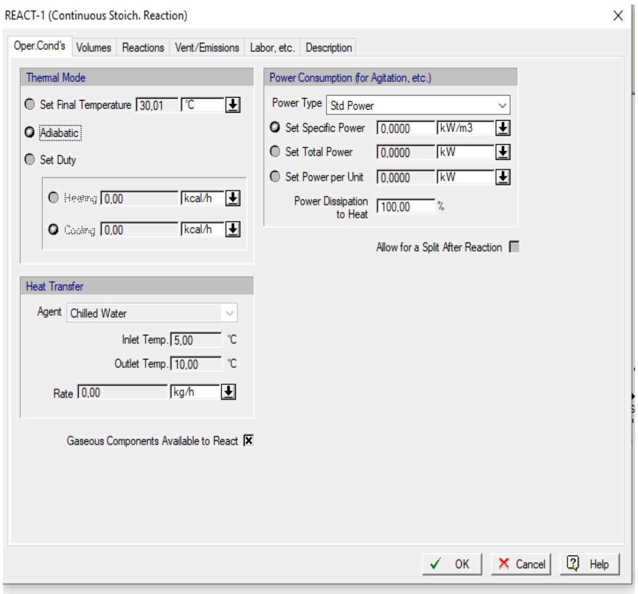
Adapun rancangan alat secara simulasi super pro dapat dilihat dibawah ini.

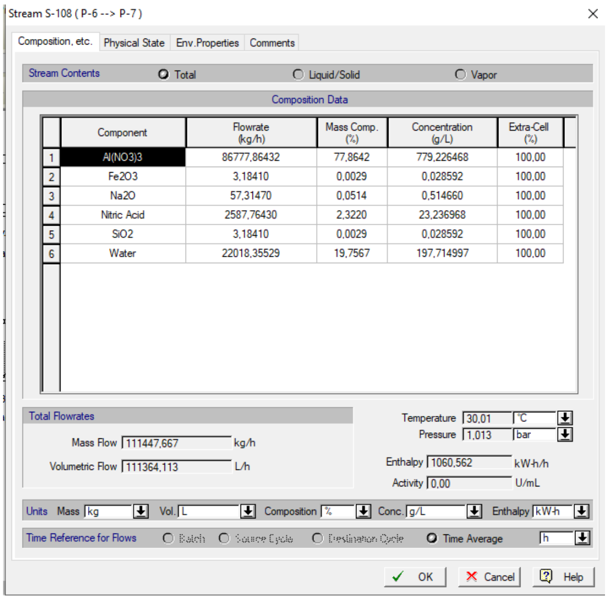
1. *Mixer* (M-

Adapun rancangan alat *mixer* secara simulasi super pro dapat dilihat dibawah ini.




Stream S-107 (P-5 --> P-6)
Composition, etc.
Physical State
Env.Properties
Comments
Stream Contents
Total
Liquid/Solid
Vapor
Composition Data
Component
Flowrate (kg/h)
Mass Comp. (%)
Concentration (g/L)
Extra-Cell (%)
1 Al(OH)3 31777,80947 99,8000 990,895792 100,00
2 Fe2O3 3,18410 0,0100 0,099287 100,00
3 Na2O 57,31470 0,1800 1,787187 100,00
4 SiO2 3,18410 0,0100 0,099287 100,00
Total Flowrates
Mass Flow 31841,492 kg/h
Volumetric Flow 32069,779 L/h
Temperature 30,00 °C
Pressure 1,013 bar
Enthalpy 256,070 kW-h/h
Activity 0,00 U/mL
Units Mass kg Vol. L Composition % Conc. g/L Enthalpy kW-h
Time Reference for Flows
Batch
Source Cycle
Destination Cycle
Time Average
h
OK
Cancel
Help

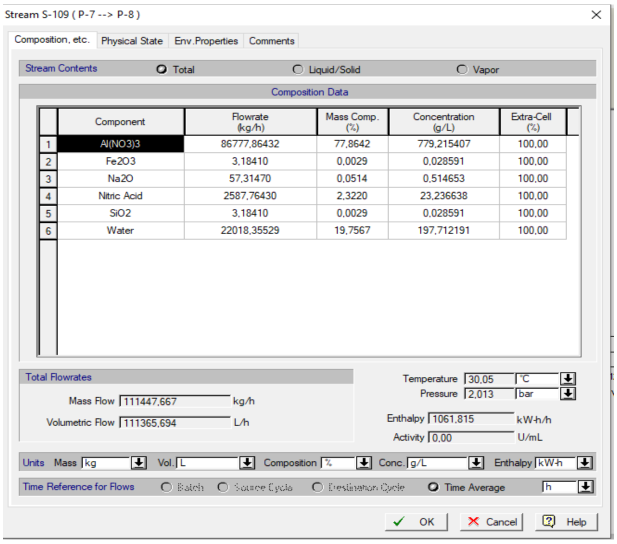

REACT-1 (Continuous Stoich. Reaction)
Oper.Cond's
Volumes
Reactions
Vent/Emissions
Labor, etc.
Description
Thermal Mode
Set Final Temperature 30,01 °C
Adiabatic
Set Duty
Heating 0,00 kcal/h
Cooling 0,00 kcal/h
Power Consumption (for Agitation, etc.)
Power Type Std Power
Set Specific Power 0,0000 kW/m3
Set Total Power 0,0000 kW
Set Power per Unit 0,0000 kW
Power Dissipation to Heat 100,00 %
Allow for a Split After Reaction
Heat Transfer
Agent Chilled Water
Inlet Temp. 5,00 °C
Outlet Temp. 10,00 °C
Rate 0,00 kg/h
Gaseous Components Available to React
OK
Cancel
Help



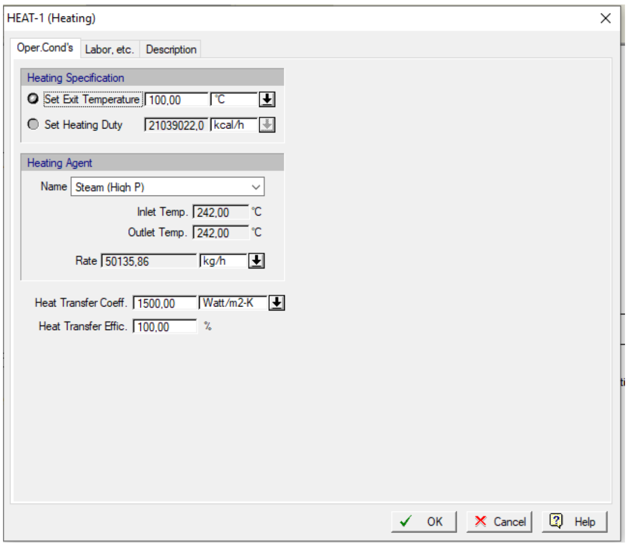
	Component	Flowrate (kg/h)	Mass Comp. (%)	Concentration (g/L)	Extra-Cell (%)
1	Al(NO3)3	86777,86432	77,8642	779,226468	100,00
2	Fe2O3	3,18410	0,0029	0,028592	100,00
3	Na2O	57,31470	0,0514	0,514660	100,00
4	Nitric Acid	2587,76430	2,3220	23,236968	100,00
5	SiO2	3,18410	0,0029	0,028592	100,00
6	Water	22018,35529	19,7567	197,714997	100,00

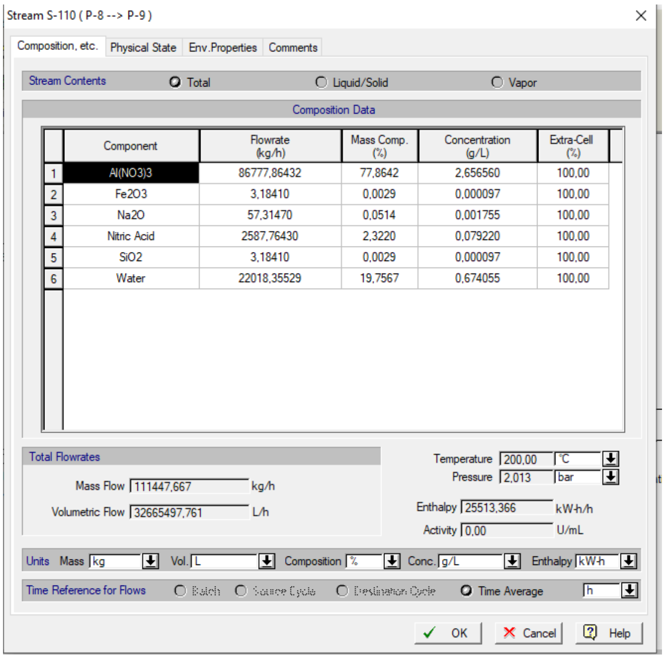
2. *Heater 1* (HE -301)

Adapun rancangan alat *Heater* secara simulasi super pro dapat dilihat dibawah ini.



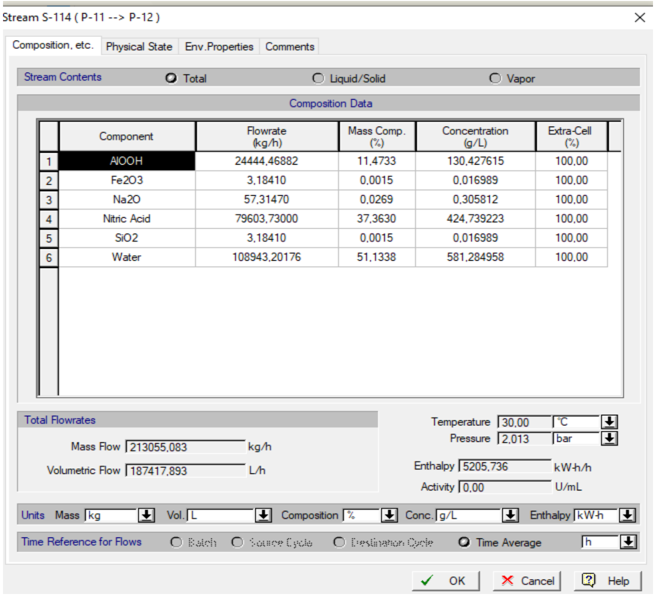
	Component	Flowrate (kg/h)	Mass Comp. (%)	Concentration (g/L)	Extra-Cell (%)
1	Al(NO3)3	86777,86432	77,8642	779,215407	100,00
2	Fe2O3	3,18410	0,0029	0,028591	100,00
3	Na2O	57,31470	0,0514	0,514653	100,00
4	Nitric Acid	2587,76430	2,3220	23,236638	100,00
5	SiO2	3,18410	0,0029	0,028591	100,00
6	Water	22018,35529	19,7567	197,712191	100,00



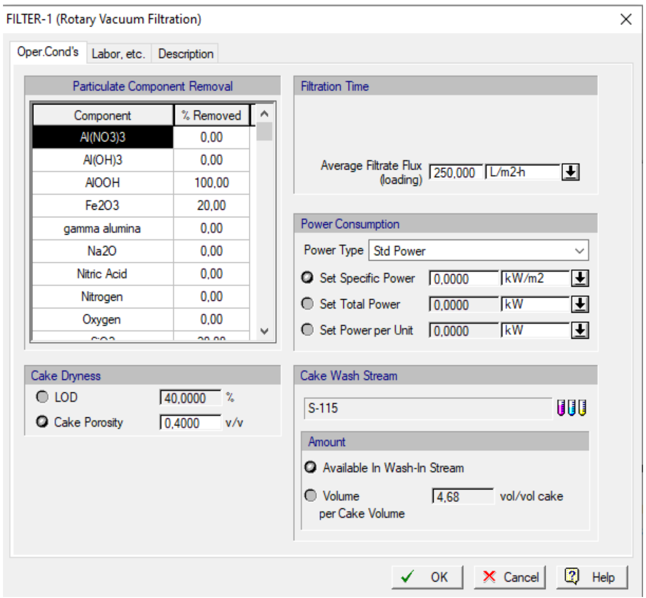


3. Rotary Vakum filter (RVF-301)

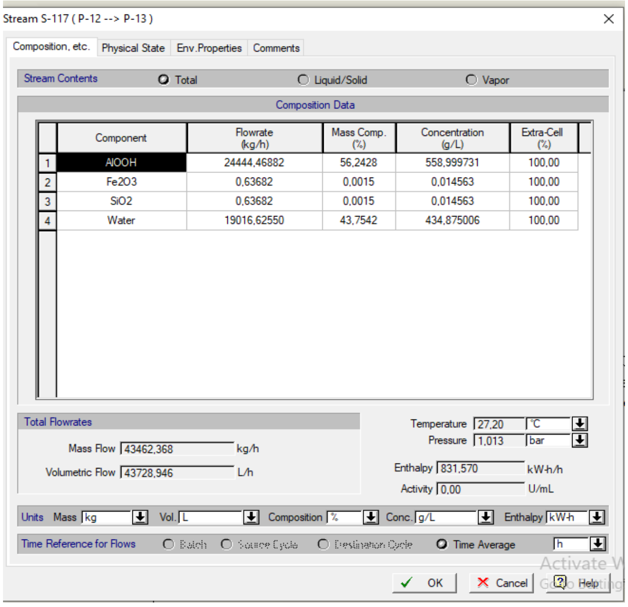
Adapun rancangan alat rotary vakum filter secara simulasi super pro dapat dilihat dibawah ini.



	Component	Flowrate (kg/h)	Mass Comp. (%)	Concentration (g/L)	Extra-Cell (%)
1	AlOOH	24444,46882	11,4733	130,427615	100,00
2	Fe2O3	3,18410	0,0015	0,016989	100,00
3	Na2O	57,31470	0,0269	0,305812	100,00
4	Nitric Acid	79603,73000	37,3630	424,739223	100,00
5	SiO2	3,18410	0,0015	0,016989	100,00
6	Water	108943,20176	51,1338	581,284958	100,00

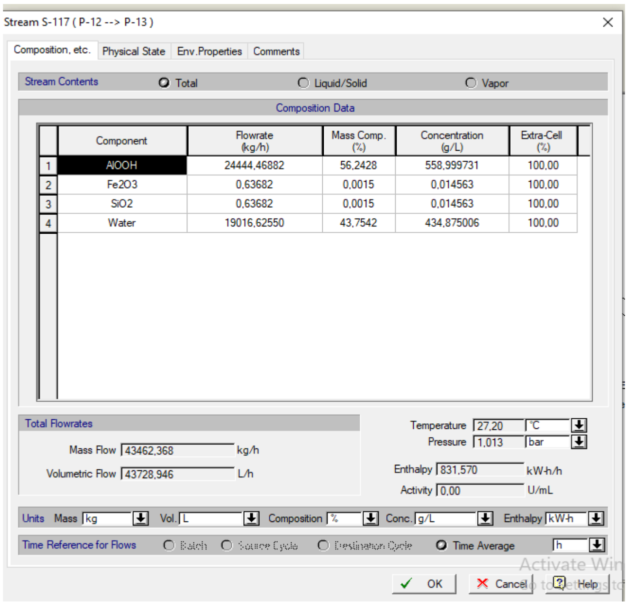


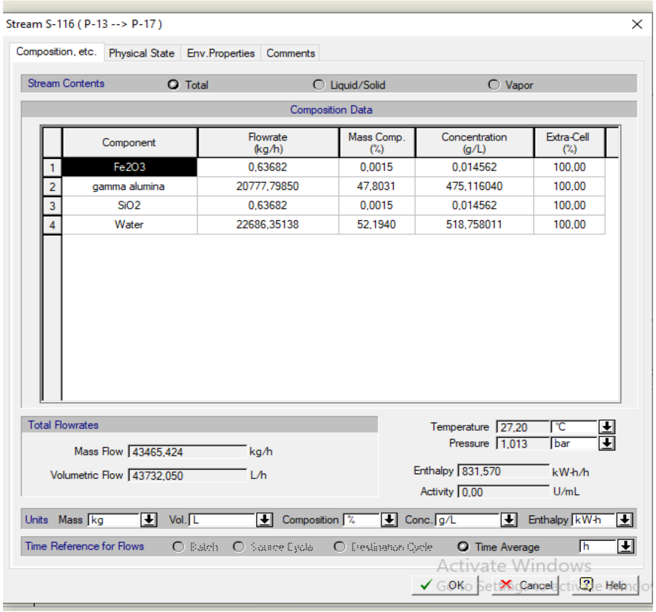
Component	% Removed
Al(NO3)3	0,00
Al(OH)3	0,00
AlOOH	100,00
Fe2O3	20,00
gamma alumina	0,00
Na2O	0,00
Nitric Acid	0,00
Nitrogen	0,00
Oxygen	0,00



4. *Rotary Klin* 1 (RK-301)

Adapun rancangan alat *Rotary Klin* secara simulasi super pro dapat dilihat dibawah ini.





Stream S-116 (P-13 --> P-17)

Composition, etc. | Physical State | Env.Properties | Comments

Stream Contents: Total / Liquid/Solid / Vapor

Composition Data

	Component	Flowrate (kg/h)	Mass Comp. (%)	Concentration (g/L)	Extra-Cell (%)
1	Fe2O3	0,63682	0,0015	0,014562	100,00
2	gamma alumina	20777,79850	47,8031	475,116040	100,00
3	SiO2	0,63682	0,0015	0,014562	100,00
4	Water	22686,35138	52,1940	518,758011	100,00

Total Flowrates

Mass Flow 43465,424 kg/h

Volumetric Flow 43732,050 L/h

Temperature 27,20 °C

Pressure 1,013 bar

Enthalpy 831,570 kW-h/h

Activity 0,00 U/mL

Units Mass kg Vol. L Composition % Conc. g/L Enthalpy kW-h

Time Reference for Flows: Batch / Source Cycle / Destination Cycle / Time Average h

OK | Cancel | Help

BAB XI
KESIMPULAN DAN SARAN

11.1 Kesimpulan

Berdasarkan uraian dan hasil perhitungan dari bab–bab sebelumnya pada pra rancangan pabrik Gamma Alumina dengan kapasitas 150.000 ton/tahun dapat disimpulkan sebagai berikut :

1. Pra rancangan pabrik Gamma Alumina dari Gibbsite dengan kapasitas 150.000 ton/tahun direncanakan untuk memenuhi kebutuhan dalam negeri dan sebagiannya di ekspor ke luar negeri.
2. Dari analisisis teknis dan ekonomi yang dilakukan, maka pabrik Gamma Alumina dari Gibbsite dengan kapasitas 150.000 ton/tahun layak didirikan di Kepulauan Riau. Pra rancangan pabrik Gamma Alumina dari Gibbsite merupakan perusahaan berbentuk Perseroan Terbatas (PT) dengan struktur organisasi *line and staff* dengan jumlah tenaga kerja 166 orang yang terdiri dari 128 karyawan shift dan 38 orang karyawan non shift.
3. Dari perhitungan analisa ekonomi, maka Pra rancangan pabrik Gamma Alumina dari Gibbsite ini ini layak didirikan dengan :
   - *Fixed Capital Investment (FCI)* =US$ 32.522.933,61
     = Rp. 508.739.988.929,10
   - *Working Capital Investment (WCI)* = US$. 21.599.202
     = Rp 337.865.510.734
   - *Total Capital Investment (TCI)* =US$ 21.599.202
     = Rp. 337.865.510.734
   - *Total Production Cost* (*TPC)* = US$ 32.522.934
     = Rp. 1.547.725.443
   - *Total Sales (TS)* =US$ 1.608.000.000
     =Rp. 23.086.458.000.000
   - *Rate of Investment (ROI)* = 43,%.
   - *Pay Out Time (POT)* = 2 tahun1 bulan 28 hari

- *Break Event Point (BEP)* = 57 %.

11.2 Saran

Berdasarkan pertimbangan dari analisa ekonomi yang telah dilakukan pabrik Gamma Alumina dari Gibbsite ini layak untuk dilanjutkan ke tahap rancangan pabrik. Untuk itu disarankan kepada pengurus dan pemilik modal untuk dapat mempertimbangkan dan mengkaji ulang tentang rancangan pabrik Gamma Alumina ini.

DAFTAR PUSTAKA

Anonim, 2008. : BHP Writes off Gag Island Laterite Resources.The Australian Business Review November, 14th.

Anonim, 2012. Nickel Ore Shipment To China.INSIGHT, No.16, April. INSG (International Nickel Study Group).

Anonim, 2012.Penanda Tanganan Kontrak PT Pasific Nickel Indonesia.

Anonim, 2014. The Most Essential and Autoritative Source for Chinese Metals Market. No 43. December.Beijing Antaike Information Development CoLtd.

Anonim, 2015, Info Mine, 24 September.

Baillie, M.G. 2002.An Update of The Weda Bay Nickel/Cobalt Laterite Project, Weda Bay Minerals Inc, ALTA.

Butt, C., 2007. Nickel laterite characteristic, classification, and processing option, August

Chalkley, M.E. dan Toirac, I.L., 1997. Hydrometallurgy and Refining of Nickel and Cobalt. Proceeding of Nickel-Cobalt 97 International Symposium. Volume 1, August 17-20, Sudbury, Ontario, Canada. p. 341-353.

Dalvi, A.D., Bacon, W.G. dan Osborne, R.C.,2004. The Past and The Future of Nickel Laterite, PDAC 2004 International Convention Trade Show & Investors Exchange, March7 – 10, 2004. INCO Limited, 2060 Flavelle Boulevard, Sheridan Park, Mississauga, Ontario L5K 1Z9, Canada.

Elias, M., 2013.Nickel Laterites in S.E Asia,Geology, Technology and Economics – Finding the Balance, in East Asia : Geology, Exploration Technologies and Mines. Principal Consultant CSA Global, Bali,May 27, 2013.

European Patent Specification, 2016. Process For Production Of Ferronickel Smelting Raw Material From Low Grade Lateritic Nickel Ore

Habashi, F., 1993. Extractive Metallurgy of Copper, Nickel, and Cobalt, Proceeding of the Paul E. Queneau International Symposium 1993.Cuba.

Jiang, K., Wang, H., Li, L.dan Liu, S., 2014. The Process Research And Development For Copper, Nickel And Cobalt In BGRIMM (Beijing General Research Institute Of Mining And Metallurgy). ALTA, Free Paper.

Jansson, M., 2014. From Indonesia to China and Back Again. Commodity Strategy, June 25, Handelsbanken Capital Market.