

APPENDIKS A
PERHITUNGAN NERACA MASSA

Data komponen:

- Berat molekul CaO	=	56,08 kg/kmol
- Berat molekul Ca(OH) ₂	=	74,10 kg/kmol
- Berat molekul SiO ₂	=	60,08 kg/kmol
- Berat molekul MgO	=	40,3 kg/kmol
- Berat molekul C	=	12,01 kg/kmol
- Berat molekul S	=	32,07 kg/kmol
- Berat molekul Al ₂ O ₃	=	101,94 kg/kmol
- Berat molekul Fe ₂ O ₃	=	159,69 kg/kmol
- Berat molekul P	=	30,98 kg/kmol
- Berat molekul Udara	=	29 kg/kmol
- Berat molekul H ₂ O	=	18,02 kg/kmol

(Perry Handbook 8th edition)

Perhitungan Kebutuhan Bahan Baku Secara Teori

$$\begin{aligned} \text{Kapasitas} &= 100000 \text{ ton/tahun} \\ &= 100000 \frac{\text{ton}}{\text{tahun}} \times \frac{1 \text{ tahun}}{330 \text{ hari}} \times \frac{1 \text{ hari}}{24 \text{ jam}} \\ &= 12,626 \text{ ton/jam} \\ &= 12626,263 \text{ kg/jam} \end{aligned}$$

$$\text{Jumlah hari kerja} = 1 \text{ tahun} = 330 \text{ hari}$$

$$\text{Jumlah waktu kerja per hari} = 1 \text{ hari} = 24 \text{ jam}$$

$$\text{Basis} = 10212,918 \text{ kg/jam CaO}$$

Komposisi bahan baku

CaO	=	94,70%	×	10212,918	=	9671,633	kg/jam
SiO ₂	=	0,65%	×	10212,918	=	66,384	kg/jam
MgO	=	1,50%	×	10212,918	=	153,194	kg/jam
C	=	0,30%	×	10212,918	=	30,639	kg/jam
S	=	0,05%	×	10212,918	=	5,106	kg/jam
Al ₂ O ₃	=	0,90%	×	10212,918	=	91,916	kg/jam
Fe ₂ O ₃	=	0,90%	×	10212,918	=	91,916	kg/jam
P	=	1,00%	×	10212,918	=	102,129	kg/jam

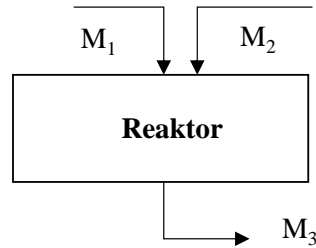
Mol Bahan Baku

CaO	=	56,08	×	9671,633	=	172,461	kmol/jam
SiO ₂	=	60,08	×	66,384	=	1,105	kmol/jam
MgO	=	40,30	×	153,194	=	3,801	kmol/jam
C	=	12,01	×	30,639	=	2,551	kmol/jam

$$\begin{aligned}
 S &= 32,07 \times 5,106 = 0,159 \text{ kmol/jam} \\
 Al_2O_3 &= 101,94 \times 91,916 = 0,902 \text{ kmol/jam} \\
 Fe_2O_3 &= 159,69 \times 91,916 = 0,576 \text{ kmol/jam} \\
 P &= 30,98 \times 102,129 = 3,297 \text{ kmol/jam}
 \end{aligned}$$

1. REAKTOR (R-110)

Fungsi : Mereaksikan antara CaO dan Air menjadi Ca(OH)₂



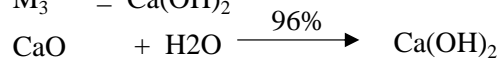
$$\text{Neraca Massa Total} : M_1 + M_2 = M_3$$

Keterangan :

$$M_1 = \text{CaO}$$

$$M_2 = \text{Air}$$

$$M_3 = \text{Ca(OH)}_2$$



Konversi : 96%

ratio

$$\text{CaO} : \text{H}_2\text{O} = 1 : 2$$

$$\text{H}_2\text{O} = 344,923 \text{ kmol/jam}$$

$$= 6215,507 \text{ kg/jam}$$

reaksi	CaO	+ H ₂ O	→	Ca(OH) ₂
m	172,461	344,923		
r	165,563	165,563		165,563
s	6,898	179,360		165,563

komposisi bahan keluar

$$\text{CaO} = 6,898 \text{ kmol/jam} = 386,865 \text{ kg/jam}$$

$$\text{SiO}_2 = 1,105 \text{ kmol/jam} = 66,384 \text{ kg/jam}$$

$$\text{MgO} = 3,801 \text{ kmol/jam} = 153,194 \text{ kg/jam}$$

$$\text{C} = 2,551 \text{ kmol/jam} = 30,639 \text{ kg/jam}$$

$$\text{S} = 0,159 \text{ kmol/jam} = 5,106 \text{ kg/jam}$$

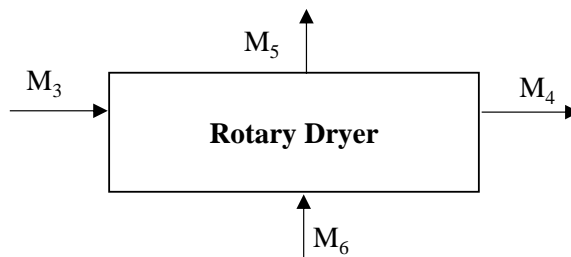
$$Al_2O_3 = 0,902 \text{ kmol/jam} = 91,916 \text{ kg/jam}$$

Fe ₂ O ₃	=	0,576	kmol/jam	=	91,916	kg/jam
P	=	3,297	kmol/jam	=	102,129	kg/jam
Ca(OH) ₂	=	165,563	kmol/jam	=	12268,211	kg/jam
H ₂ O sisa	=	179,360	kmol/jam	=	3232,064	kg/jam

Neraca Massa pada Reaktor (R-110)	
Masuk(kg/jam)	Keluar(kg/jam)
M ₁ dari Bin CaO (F-113)	M ₃ ke Rotary Dryer (B - 120)
CaO = 9671,633	CaO = 386,865
SiO ₂ = 66,384	SiO ₂ = 66,384
MgO = 153,194	MgO = 153,194
C = 30,639	C = 30,639
S = 5,106	S = 5,106
Al ₂ O ₃ = 91,916	Al ₂ O ₃ = 91,916
Fe ₂ O ₃ = 91,916	Fe ₂ O ₃ = 91,916
P = 102,129	P = 102,129
10212,918	Ca(OH) ₂ = 12268,211
M ₂ dari water process	H ₂ O sisa = 3232,064
H ₂ O = 6215,507	
Total = 16428,425	Total = 16428,425

2. Rotary Dryer (B-120)

Fungsi : Mengurangi kadar air yang terkandung dalam produk Ca(OH)₂



$$\text{Neraca Massa Total} : M_3 + M_6 = M_4 + M_5$$

Keterangan :

M₃ = Massa slurry dari reaktor

M₄ = Massa bahan kering ke bin produk

M₅ = Massa udara bercampur debu masuk ke cyclone

M₆ = Massa udara panas masuk ke rotary dryer

Komposisi bahan masuk:

CaO	=	386,865	kg/jam
SiO ₂	=	66,384	kg/jam
MgO	=	153,194	kg/jam
C	=	30,639	kg/jam
S	=	5,106	kg/jam
Al ₂ O ₃	=	91,916	kg/jam
Fe ₂ O ₃	=	91,916	kg/jam
P	=	102,129	kg/jam
Ca(OH) ₂	=	12268,211	kg/jam
H ₂ O	=	3232,064	kg/jam

Kandungan air dalam produk 0,75% Ca(OH)₂

$$0,75\% = \frac{\text{massa air}}{\text{Massa padatan} + \text{massa air}} \times 100\%$$

$$0,75\% \times 13196,361 + \text{massa air} = \text{massa air} \times 100\%$$

$$\begin{aligned} 98,972708 + 0,75\% \text{ massa} &= 100\% \text{ massa air} \\ 99,25\% \text{ massa air} &= 98,973 \\ \text{massa air} &= 99,721 \end{aligned}$$

Asumsi bahan masuk cyclone sebesar = 2%

CaO	=	0,02 × 386,865	=	7,737	kg/jam
SiO ₂	=	0,02 × 66,384	=	1,328	kg/jam
MgO	=	0,02 × 153,194	=	3,064	kg/jam
C	=	0,02 × 30,639	=	0,613	kg/jam
S	=	0,02 × 5,106	=	0,102	kg/jam
Al ₂ O ₃	=	0,02 × 91,916	=	1,838	kg/jam
Fe ₂ O ₃	=	0,02 × 91,916	=	1,838	kg/jam
P	=	0,02 × 102,129	=	2,043	kg/jam
Ca(OH) ₂	=	0,02 × 12268,211	=	245,364	kg/jam
H ₂ O	=	3232,06 - 99,7206	=	3132,34	kg/jam

Asumsi bahan masuk bin cake Ca(OH)₂ sebesar = 98%

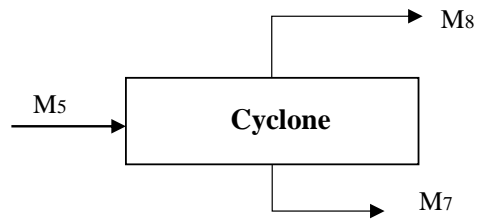
CaO	=	0,98 × 386,865	=	379,128	kg/jam
SiO ₂	=	0,98 × 66,384	=	65,056	kg/jam
MgO	=	0,98 × 153,194	=	150,130	kg/jam
C	=	0,98 × 30,639	=	30,026	kg/jam

S	=	0,98	×	5,106	=	5,004	kg/jam
Al ₂ O ₃	=	0,98	×	91,916	=	90,078	kg/jam
Fe ₂ O ₃	=	0,98	×	91,916	=	90,078	kg/jam
P	=	0,98	×	102,129	=	100,087	kg/jam
Ca(OH) ₂	=	0,98	×	12268,211	=	12022,847	kg/jam
H ₂ O	=				=	99,721	kg/jam

Neraca Massa pada Rotary Dryer (B-120)	
Masuk (kg/jam)	Keluar (kg/jam)
M ₃ dari Reaktor (R-110)	M ₄ ke Cooling Conveyor (J-132)
CaO = 386,865	CaO = 379,128
SiO ₂ = 66,384	SiO ₂ = 65,056
MgO = 153,194	MgO = 150,130
C = 30,639	C = 30,026
S = 5,106	S = 5,004
Al ₂ O ₃ = 91,916	Al ₂ O ₃ = 90,078
Fe ₂ O ₃ = 91,916	Fe ₂ O ₃ = 90,078
P = 102,129	P = 100,087
Ca(OH) ₂ = 12268,211	Ca(OH) ₂ = 12022,847
H ₂ O = 3232,064	H ₂ O = 99,721
	13032,154
	M ₅ ke Cyclone (H-131)
	CaO = 7,737
	SiO ₂ = 1,328
	MgO = 3,064
	C = 0,613
	S = 0,102
	Al ₂ O ₃ = 1,838
	Fe ₂ O ₃ = 1,838
	P = 2,043
	Ca(OH) ₂ = 245,364
	H ₂ O = 3132,343
	3396,270
Total = 16428,425	Total = 16428,425

3. Cyclone (H-131)

Fungsi : Memisahkan debu partikel bahan kering yang terikut udara dari rotary dryer



$$\text{Neraca Massa Total} \quad : \quad M_5 = M_7 + M_8$$

Keterangan:

M_5 = Massa udara bercampur debu masuk ke cyclone

M_7 = Massa partikel bahan kering yang masuk hammer mill

M_8 = Massa gas dan debu yang keluar

Komposisi bahan masuk:

CaO	=	7,737	kg/jam
SiO ₂	=	1,328	kg/jam
MgO	=	3,064	kg/jam
C	=	0,613	kg/jam
S	=	0,102	kg/jam
Al ₂ O ₃	=	1,838	kg/jam
Fe ₂ O ₃	=	1,838	kg/jam
P	=	2,043	kg/jam
Ca(OH) ₂	=	245,364	kg/jam
H ₂ O	=	3132,34	kg/jam

Produk atas Cyclone

asumsi	=	2%
CaO	=	0,155 kg/jam
SiO ₂	=	0,027 kg/jam
MgO	=	0,061 kg/jam
C	=	0,012 kg/jam
S	=	0,002 kg/jam
Al ₂ O ₃	=	0,037 kg/jam
Fe ₂ O ₃	=	0,037 kg/jam
P	=	0,041 kg/jam
Ca(OH) ₂	=	4,907 kg/jam
H ₂ O	=	3132,34 kg/jam

Produk bawah Cyclone

asumsi = 98%

CaO = 7,583 kg/jam

SiO₂ = 1,301 kg/jam

MgO = 3,003 kg/jam

C = 0,601 kg/jam

S = 0,100 kg/jam

Al₂O₃ = 1,802 kg/jamFe₂O₃ = 1,802 kg/jam

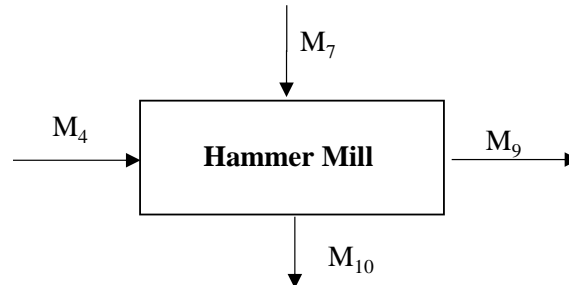
P = 2,002 kg/jam

Ca(OH)₂ = 240,457 kg/jam

Neraca Massa pada Cyclone			
Masuk (kg/jam)		Keluar (kg/jam)	
M ₈ dari Rotary Dryer (B-120)		M ₁₀ ke Hammer Mill (C-138)	
CaO	= 7,737	CaO	= 7,583
SiO ₂	= 1,328	SiO ₂	= 1,301
MgO	= 3,064	MgO	= 3,003
C	= 0,613	C	= 0,601
S	= 0,102	S	= 0,100
Al ₂ O ₃	= 1,838	Al ₂ O ₃	= 1,802
Fe ₂ O ₃	= 1,838	Fe ₂ O ₃	= 1,802
P	= 2,043	P	= 2,002
Ca(OH) ₂	= 245,364	Ca(OH) ₂	= 240,457
H ₂ O	= 3132,343		258,649
		M ₁₁ keluar cyclone	
		CaO	= 0,155
		SiO ₂	= 0,027
		MgO	= 0,061
		C	= 0,012
		S	= 0,002
		Al ₂ O ₃	= 0,037
		Fe ₂ O ₃	= 0,037
		P	= 0,041
		Ca(OH) ₂	= 4,907
		H ₂ O	= 3132,343
			3137,622
Total	= 3396,270	Total	= 3396,270

4 Hammer Mill (C-130)

Fungsi: Merubah ukuran partikel menjadi 325 mesh



$$\text{Neraca Massa Total} : M_4 + M_7 = M_9 + M_{10}$$

M_4 = Massa bahan dari rotary dryer

M_7 = Massa bahan dari cyclone

M_9 = Massa Ca(OH)_2 produk

M_{10} = Massa Recycle Hammer Mill

Massa bahan dari rotary dryer

CaO = 379,128 kg/jam

SiO₂ = 65,056 kg/jam

MgO = 150,130 kg/jam

C = 30,026 kg/jam

S = 5,004 kg/jam

Al₂O₃ = 90,078 kg/jam

Fe₂O₃ = 90,078 kg/jam

P = 100,087 kg/jam

Ca(OH)₂ = 12022,847 kg/jam

H₂O = 99,721 kg/jam

Massa bahan dari cyclone

CaO = 7,583 kg/jam

SiO₂ = 1,301 kg/jam

MgO = 3,003 kg/jam

C = 0,601 kg/jam

S = 0,100 kg/jam

Al₂O₃ = 1,802 kg/jam

Fe₂O₃ = 1,802 kg/jam

P = 2,002 kg/jam

Ca(OH)₂ = 240,457 kg/jam

Massa Ca(OH)₂ produk

CaO	=	379,128	+	7,583	=	386,711	kg/jam
SiO ₂	=	65,056	+	1,301	=	66,357	kg/jam
MgO	=	150,130	+	3,003	=	153,132	kg/jam
C	=	30,026	+	0,601	=	30,626	kg/jam
S	=	5,004	+	0,100	=	5,104	kg/jam
Al ₂ O ₃	=	90,078	+	1,802	=	91,879	kg/jam
Fe ₂ O ₃	=	90,078	+	1,802	=	91,879	kg/jam
P	=	100,087	+	2,002	=	102,088	kg/jam
Ca(OH) ₂	=	12022,847	+	240,457	=	12263,304	kg/jam

Massa Recycle Hammer Mill, asumsi = 5%

CaO	=	19,336	kg/jam
SiO ₂	=	3,318	kg/jam
MgO	=	7,657	kg/jam
C	=	1,531	kg/jam
S	=	0,255	kg/jam
Al ₂ O ₃	=	4,594	kg/jam
Fe ₂ O ₃	=	4,594	kg/jam
P	=	5,104	kg/jam
Ca(OH) ₂	=	613,165	kg/jam
H ₂ O	=	4,986	kg/jam

Neraca Massa pada Hammer Mill (C-130)	
Masuk (kg/jam)	Keluar (kg/jam)
M ₄ dari Rotary Dryer (B-120)	M ₉ ke mesin pengemas (J-136)
CaO = 379,128	CaO = 367,375
SiO ₂ = 65,056	SiO ₂ = 63,040
MgO = 150,130	MgO = 145,476
C = 30,026	C = 29,095
S = 5,004	S = 4,849
Al ₂ O ₃ = 90,078	Al ₂ O ₃ = 87,286
Fe ₂ O ₃ = 90,078	Fe ₂ O ₃ = 87,286
P = 100,087	P = 96,984
Ca(OH) ₂ = 12022,847	Ca(OH) ₂ = 11650,139
H ₂ O = 99,721	H ₂ O = 94,735
<u>13032,154</u>	<u>12626,263</u>

M ₇ dari Cyclone (H-131)			M ₁₀ recycle		
CaO	=	7,583	CaO	=	19,336
SiO ₂	=	1,301	SiO ₂	=	3,318
MgO	=	3,003	MgO	=	7,657
C	=	0,601	C	=	1,531
S	=	0,100	S	=	0,255
Al ₂ O ₃	=	1,802	Al ₂ O ₃	=	4,594
Fe ₂ O ₃	=	1,802	Fe ₂ O ₃	=	4,594
P	=	2,002	P	=	5,104
Ca(OH) ₂	=	240,457	Ca(OH) ₂	=	613,165
		<u>258,649</u>	H ₂ O	=	4,986
					<u>664,540</u>
Total	=	13290,803	Total	=	13290,803