

BAB V
NERACA MASSA

1.1 Neraca Massa Keseluruhan

Basis perhitungan neraca massa:

Kapasitas produk : 7000 ton per tahun

Diambil dalam satu tahun kerja : 330 harian kerja

1 hari kerja : 24 jam

Kapasitas produksi : 7000 ton per tahun

:7000

$$\frac{\text{ton}}{\text{tahun}} \times \frac{1000 \text{ kg}}{1 \text{ tahun}} \times \frac{1 \text{ tahun}}{330 \text{ hari}} \times \frac{1 \text{ hari}}{24 \text{ jam}}$$

: 883,83838 kg/jam

Proses yang terjadi : kontinyu

Neraca massa tanpa reaksi:

$$\text{Akumulasi} = \text{input} - \text{output} + \text{generasi} - \text{konsumsi}$$

Diasumsikan bahwa proses dalam keadaan steady state sehingga akumulasi = 0. Karena tidak ada reaksi sehingga generasi dan konsumsi = 0, maka persamaan neraca massa menjadi:

$$0 = \text{input} - \text{output} + 0 - 0$$

$$\text{Input} = \text{output}$$

Neraca massa dengan reaksi:

$$\text{Akumulasi} = \text{input} - \text{output} + \text{gnenerasi} - \text{konsumsi}$$

Asumsi dalam keadaan stady state, sehingga akumulasi = 0 maka persamaan neraca massa menjadi:

$$0 = \text{input} - \text{output} + \text{generasi} - \text{konsumsi}$$

$$\text{Input} = \text{output} - \text{generasi} + \text{konsumsi}$$

Data berat molekul

H₂O = 18, 01528 g/mol

H₂SO₄ = 98,079 g/mol

NaNO ₃	= 84,9947 g/mol
O ₂	= 16 g/mol
HNO ₃	= 63,01 g/mol
NO ₂	= 46,0055 g/mol
NO	= 259 u
NaHSO ₄	= 120,06 g/mol

2.1.1 Neraca Massa Keseluruhan Reaktor

Komponen-kmponen dalam tangki pencampur terdiri dari H₂O, H₂SO₄, maka perhitungan neraca massanya adalah sebagai berikut:

$$\text{H}_2\text{O} = 18,01528 \text{ g/mol}$$

$$\text{H}_2\text{SO}_4 = 98,079 \text{ g/mol}$$

Basis ; 100 kg NaNO₃

$$\text{Kadar NaNO}_3 = 98 \%$$

$$\text{H}_2\text{O} = 2 \text{ kg}$$

$$\text{NaNO}_3 \text{ masuk} = 100 \text{ kg} = 1,176470588 \text{ kmol}$$

Konversi 0,97

$$\text{NaNO}_3 \text{ reaksi} = 1,176470588 \times 0,97$$

$$= 1,141176471 \text{ kmol}$$

$$\text{NaNO}_3 \text{ sisa} = 1,176470588 - 1,141176471$$

$$= 0,035294118 \text{ kmol}$$

$$= 3 \text{ kg}$$



H₂SO₄ yang diumpankan ekimolar

$$\text{H}_2\text{SO}_4 \text{ masuk} = 1,176470588 \text{ kmol}$$

$$= 115,2941176 \text{ kg}$$

$$\text{H}_2\text{SO}_4 \text{ reaksi} = 1,141176471 \text{ kmol}$$

$$= 111,8352941 \text{ kg}$$

$$\text{H}_2\text{SO}_4 \text{ sisa} = 3,458823529 \text{ kg}$$

$$\text{Kadar H}_2\text{SO}_4 = 93\%$$

$$\text{H}_2\text{O dlm H}_2\text{SO}_4 = (7/100) \times 115,2941176 \text{ kg} = 8,070588235 \text{ kg}$$

$$\begin{aligned}
 \text{NaHSO}_4 \text{ hasil} &= 1,141176471 \text{ kmol} \\
 &= 136,9297647 \text{ kg} \\
 \text{HNO}_3 \text{ hasil} &= 1,141176471 \text{ kmol} \\
 &= 71,89411765 \text{ kg} \\
 \text{H}_2\text{O total dalam reaktor} &= \text{H}_2\text{O dlm NaNO}_3 + \text{H}_2\text{O dlm H}_2\text{SO}_4 \\
 &= 2 + 8,070588235 \\
 &= 10,07058824 \text{ kg} \\
 \text{Asumsi: H}_2\text{O dalam Either Cake} &= 10 \% \\
 &= 10/100 \times 10,07058824 \text{ kg} \\
 &= 1,007058824 \text{ kg} \\
 \text{H}_2\text{O keluar reaktor} &= 10,07058824 \text{ kg} - 1,007058824 \text{ kg} \\
 &= 9,063529412 \text{ kg}
 \end{aligned}$$

Tabel 5. 1 Neraca massa keseluruhan reaktor

Komposisi	Masuk	Keluar	
		Ke separator	Either cake
HNO ₃		71,89411765	
NaNO ₃	100		3
H ₂ SO ₄	115,294118		3,458823529
NaHSO ₄			136,9297647
H ₂ O	10,0705882	9,063529412	1,007058824
TOTAL	225,364706	80,95764706	144,3956471
		225,367059	

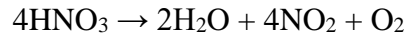
2.1.2 Neraca Massa Keseluruhan Condensor

Bahan-bahan yang masuk ke dalam kondensor

Komponen	Kg	Kmol
HNO ₃	71,8941176	1,141176471
H ₂ O	9,06352941	0,503529412
		1,644705882

HNO₃ terdekomposisi

Reaksi



$$\begin{aligned}\text{Asumsi HNO}_3 \text{ terdekomposisi sebesar} &= 10 \% \\ &= 7,189411765 \text{ kg} \\ &= 0,114117647 \text{ kmol}\end{aligned}$$

$$\begin{aligned}\text{HNO}_3 \text{ sisa} &= \text{HNO}_3 \text{ cair} - \text{HNO}_3 \text{ terdekomposisi} \\ &= 71,8941176 \text{ kg} - 7,189411765 \text{ kg} \\ &= 64,7047 \text{ kg}\end{aligned}$$

$$\text{HNO}_3 \text{ reaksi} = 0,114117647 \text{ kmol}$$

$$\begin{aligned}\text{H}_2\text{O} \text{ terbentuk} &= \frac{1}{2} \times 0,114117647 \text{ kmol} \\ &= 0,057058824 \text{ kmol} \\ &= 1,027058824 \text{ kg}\end{aligned}$$

$$\begin{aligned}\text{NO}_2 \text{ terbentuk} &= 0,114117647 \text{ kmol} \\ &= 5,249411765 \text{ kg}\end{aligned}$$

$$\begin{aligned}\text{O}_2 \text{ terbentuk} &= \frac{1}{4} \times 0,114117647 \text{ kmol} \\ &= 0,028529412 \text{ kmol} \\ &= 0,912941176 \text{ kg}\end{aligned}$$

$$\begin{aligned}\text{H}_2\text{O} \text{ uap} &= \text{H}_2\text{O} \text{ uap} + \text{H}_2\text{O} \text{ terbentuk} \\ &= 9,0635 + 1,27058824 \\ &= 10,09058824\end{aligned}$$

$$\text{Log } P = A + B/T + \text{Log} (T + DT + ET^2)$$

Komponen	A	B	C	D	E
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H ₂ O	29,8605	-	-	2,42E-	1,81E-
HNO ₃	71,7653	3,51E+03	7,30E+00	09	06
		-	-2,28E-07	-4,60E-	1,19E-
		4,38E+03		07	05

Tekanan operasi ditetapkan 1 atm

Suhu operasi = 95°C = 368,0638⁰K

$K = P/P_t$

$P = \text{Tekanan parsial gas} = 1 \text{ atm} = 760 \text{ mmHg}$

$P_t = \text{Tekanan total}$

$V/L \text{ Trial} = 0,775$

Harga L trial didapatkan harga pada tabel berikut.

Komponen	Berat	Kmol	Fraksi mol	Pi	K
HNO ₃	64,7047	1,02705873	0,646906	1138,55655	1,49810072
H ₂ O	10,0906	0,56058889	0,353094	66,4458546	0,08742876
		1,58764762	1		

Komponen	Berat	$L=Fi/(VK/L+1)$	$V=Fi-Li$	BM	Cair	Uap
HNO ₃	64,7047	0,4753	0,5518	63	29,941629	34,7631
H ₂ O	10,0906	0,525	0,0356	18	9,450275	0,6403
		1,0003	0,5874		39,391904	35,4034

Tabel 5. 2 neraca massa keseluruhan kondensor

Komponen	Masuk	Keluar
HNO ₃	71,8941176	64,7047
H ₂ O	9,06352941	10,0906

O ₂		5,2494
NO ₂		0,9129
Total	80,957647	80,957647

2.1.3 Neraca Massa Keseluruhan Separator

Tabel 5. 3 Neraca Massa Keseluruhan Separator

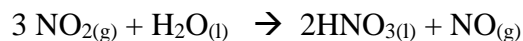
Komponen	Masuk	Keluar	
		Cair	Uap
H ₂ O	9,06352941	9,4503	0,6403
HNO ₃	71,8941176	29,9416	34,7631
O ₂			5,2494
NO ₂			0,9129
TOTAL	80,957647	39,391904	41,56575294
		80,957647	

2.1.4 Neraca Massa Keseluruhan Absorber

Komposisi bahan masuk

Komponen	Masuk	Kmol	Fraksimol
H ₂ O	0,6403	0,035572222	0,046122331
HNO ₃	34,7631	0,551795238	0,715448201
O ₂	5,2491176	0,164044118	0,212696777
NO ₂	0,91294118	0,019845647	0,025732691
TOTAL	41,5658	0,771258125	1

Reaksi 1 :



Konversi = 90%

NO₂ sisa = (100% - 90%) x XNO₂

= 10% x 0,01984655

= 0,001984655 kmol = 0,091294118 kg

H₂O berreaksi = 1/3 x 90% x XNO₂

$$= 1/3 \times 90\% \times 0,01984655 \text{ kmol}$$

$$= 0,005953964 \text{ kmol} = 0,107171355 \text{ kg}$$

$$\text{NO terbentuk} = 1/3 \times 90\% \times \text{XNO}_2$$

$$= 1/3 \times 90\% \times 0,01984655 \text{ kg}$$

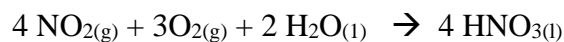
$$= 0,005953964 \text{ kmol} = 0,178618926 \text{ kg}$$

$$\text{HNO}_3 \text{ terbentuk} = 2/3 \times 90\% \times \text{XNO}_2$$

$$= 2/3 \times 90\% \times 0,01984655 \text{ kmol}$$

$$= 0,011907928 \text{ kmol} = 0,750199488 \text{ kg}$$

Reaksi 2:



Konversi = 90%

$$\text{NO berreaksi} = 90\% \times 0,005953964 \text{ kmol}$$

$$= 0,005358568 \text{ kmol}$$

$$= 0,160757033 \text{ kg}$$

$$\text{NO sisa} = 0,178618926 - 0,160757033 \text{ kg}$$

$$= 0,017861893 \text{ kg}$$

$$\text{O}_2 \text{ sisa} = 0,164044118 \text{ kmol} - (3/4 \times 90\% \times 0,005953964 \text{ kmol})$$

$$= 0,160025192 \text{ kmol}$$

$$= 5,120806138 \text{ kg}$$

$$\text{H}_2\text{O berreaksi} = 2/4 \times 90\% \times 0,005953964 \text{ kmol}$$

$$= 0,002679284 \text{ kmol}$$

$$= 0,04822711 \text{ kg}$$

$$\text{HNO}_3 \text{ terbentuk} = 4/4 \times 90\% \times 0,005953964 \text{ kmol}$$

$$= 0,005358568 \text{ kmol}$$

$$= 0,3375897 \text{ kg}$$

$$\text{H}_2\text{O yang bereaksi} = 0,107171355 + 0,04822711$$

$$= 0,155398465 \text{ kg}$$

Jumlah HNO₃ 100% wt terbentuk dari dua reaksi diatas:

$$= 0,750199488 + 0,33758977 + 34,7631 = 35,8509 \text{ kg}$$

Jumlah H₂O yang dibutuhkan untuk membentuk HNO₃ 65% wt:

$$= 35\% / 65\% \times 35,8509 \text{ kg}$$

$$= 19,30432499 \text{ kg}$$

Jumlah H₂O total yang dibutuhkan:

$$= 19,30432499 + 0,155398465 - 0,6403$$

$$= 18,8194 \text{ kg}$$

Tabel 5. 4 Neraca Massa Keseluruhan Absorber

Komponen	Masuk		Keluar	
	Masuk	Make up	Uap	Cair
HNO ₃	34,7631			35,850889
H ₂ O	0,6403	18,81942345		19,304325
O ₂	5,24941176		5,120806138	
NO ₂	0,91294118		0,091294118	
NO			0,017861893	
TOTAL	41,5657529	18,81942345	5,229962148	55,155214
	60,38517639		60,38517639	

Accumulator

Dari hasil bawah absorber

$$\text{HNO}_3 : 35,85088926$$

$$\text{H}_2\text{O} : \underline{19,30432499} +$$

$$55,15521424$$

Hasil bawah separator

$$\text{HNO}_3 : 29,9416$$

$$\text{H}_2\text{O} : \underline{9,4503} +$$

$$: 39,391904$$

Keluar accumulator

$$\text{HNO}_3 : 64,7047 \quad + \quad 1,08778926 \quad = 65,7925 \text{ kg}$$

$$\text{H}_2\text{O} : \underline{10,0906} \quad + \quad 1,4419532 \quad = 28,7546 \text{ kg}$$

_____ +

$$\text{Total} \quad = 94,5471 \text{ kg}$$

Kapasitas produksi = 7000 ton/tahun

Catatan : pabrik beroperasi selama 330 hari dalam 1 tahun

$$\text{Kecepatan produksi} = \frac{883,83838}{94,54711824} = 9,348126101$$

1.2 Neraca Massa Kapasitas

5.2.1 Neraca Massa Kapasitas Reaktor

Tabel 5. 5 Neraca Massa Kapasitas Reaktor

Komposisi	Masuk	Keluar	
		Ke separator	Either cake
HNO ₃	934,8126101	672,0752777	28.044387
NaNO ₃			
H ₂ SO ₄			
NaHSO ₄			
H ₂ O	94,1411474	84,72701586	9,4141129
TOTAL	2106,73689	756,8022936	1321,95967
		2106,73689	

5.2.2 Neraca Massa Kapasitas Condensor

Tabel 5. 6 Neraca Massa Kapasitas Condensor

Komponen	Masuk	Keluar
HNO ₃	672,075277	604,86769
H ₂ O	84,7270158	94,3282
O ₂		49,07216
NO ₂		8,53429
Total	756,80229	765,80229

5.2.3 Neraca Massa Kapasitas Separator

Tabel 5. 7 Neraca Massa Kapasitas Separator

Komponen	Masuk	Keluar	
		Cair	Uap

H ₂ O	84,727033	88,3426	5,9856
HNO ₃	672,075413	279,8979	324,9699
O ₂			49,0720
NO ₂			8,5339
TOTAL	756,8022	368,2405	388,5665
		756,8022	

5.2.4 Neraca Massa Kapasitas Absorber

Tabel 5. 8 Neraca Massa Kapasitas Absorber

Komponen	Masuk		Keluar	
	Masuk	Make up	Uap	Cair
HNO ₃	324,969908			335,138699
H ₂ O	5,985606	175,926379		180,459301
O ₂	49,072173		47,869951	
NO ₂	8,534294		0,853429	
NO			0,166975	
TOTAL	388,561981	175,926379	48,890355	515,598
	564,4883		564,4883	