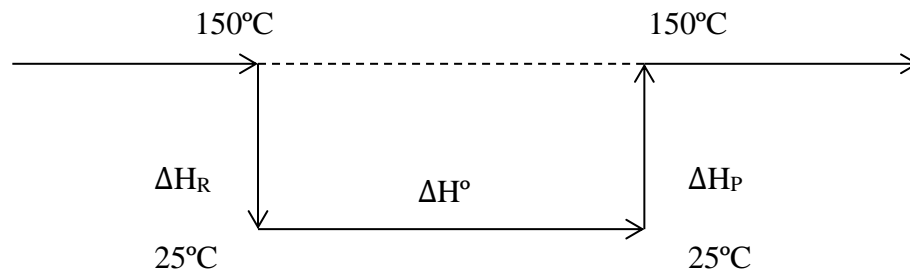


BAB VI NERACA PANAS

1.1 Neraca Panas Reaktor

Profil suhu reaksi



$$C_p \text{ NaHSO}_4 : 223,515 - 9,527 \cdot 10^{-3}T - 3,406 \cdot 10^{-5}T^2 + 1,5771 \cdot 10^{-8} T^3$$

$$C_p \text{ HNO}_3 : 214,478 - 7,676 \cdot 10^{-1}T + 1,497 \cdot 10^{-3}T^2 - 3,0208 \cdot 10^{-7} T^3$$

$$C_p \text{ H}_2\text{SO}_4 : 26,004 + 7,0337 \cdot 10^{-1}T - 1,385 \cdot 10^{-3}T^2 + 1,0324 \cdot 10^{-6} T^3$$

$$C_p \text{ H}_2\text{O} : 92,053 - 3,9953 \cdot 10^{-2}T - 2,1103 \cdot 10^{-4}T^2 + 5,3469 \cdot 10^{-7}T^3$$

Kkal /Kmol °K (C. Yaws 1984)

$$C_p \text{ NaNO}_3 : -15,5 + 1,0144T - 4,369E-3T^2 + 9,345E-6T^3 - 6,1283E-9T^4$$

$$C_p \text{ NO}_2 \text{ (g)} : 25,1165 + 4,39956E-2T - 9,61717E-6T^2 - 1,21653E-8T^3 + 5,44943E-12T^4$$

$$C_p \text{ O}_2 \text{ (g)} : 29,8832 + 1,13842E-2T + 4,33779E-5T^2 - 3,70062E-8T^3 + 1,01006E-11T^4$$

$$C_p \text{ NO (g)} : 29,7657 + 9,7605E-4T + 6,09872E-6T^2 - 3,58809E-9T^3 + 5,85308E-13T^4$$

KJ/kmol °K (Reklaitis, 1983)

a. Menentukan ΔH_1

Suhu masuk = 150°C

Suhu ref = 25°C

Komponen n	m (kg)	n (Kmol)	Cp dT (Kkal/Kmol)	Q (Kkal)
NaNO ₃	934,81261	10,998148	352,049224 9	38717,6535 1
H ₂ O	18,69625	1,03868066 7	946,914877 9	9835,42176 7
H ₂ SO ₄	1077,7839 5	10,9977954 1	1844,91267 6	202899,721 6
H ₂ O	75,444877	4,19138205 6	946,914877 9	39688,8202 8
				291141,617 1

b. Menentukan ΔH_2

Untuk keluar reaktor suhu 150°C

a) Hasil

Komponen n	m (kg)	n (Kmol)	Cp (Kkal/kmol)	Q (Kkal)
HNO ₃	672,07527 7	10,6678615	1495,99840 7	159591,038 9
H ₂ O	84,727015 8	4,70705643 7	946,914877 9	44571,8177 1
				204162,856 6

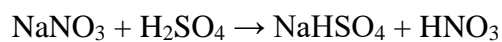
b) Either cake

Komponen	m (kg)	n (kmol)	Cp (Kkal/kmol)	Q (Kkal)
NaNO ₃	28,04437 8	0,32993385 8	352,049224 9	1161,52959 3
H ₂ O	94,14112 9	0,52300627 2	946,914877 9	4952,42420 4
H ₂ SO ₄	32,33351 9	0,32993386 7	1844,91267 6	6086,99174 1
NaHSO ₄	1280,036 7	10,6669725	2704,62163 3	288501,245 8
				300702,191 3

$$\begin{aligned}
\text{Maka } \Delta H_{2 \text{ total}} &= \Delta H_{2 \text{ hasil}} + \Delta H_{2 \text{ cake}} \\
&= 204162,8566 + 300702,1913 \\
&= 504865,0479 \text{ kkal}
\end{aligned}$$

Menentukan panas reaksi

Reaksi :



$$\Delta H_{f(298)} \text{ NaHSO}_4 \quad : - 269,20$$

$$\Delta H_{f(298)} \text{ HNO}_3 \quad : -41,404$$

$$\Delta H_{f(298)} \text{ H}_2\text{SO}_4 \quad : -193,91$$

$$\Delta H_{f(298)} \text{ H}_2\text{O} \quad : -68,317$$

$$\Delta H_{f(298)} \text{ NaNO}_3 \quad : - 101,54 \text{ Kkal/gmol (Van Ness)}$$

$$\Delta H_{(298)} = (\Delta H_f \text{ HNO}_3 + \Delta H_f \text{ NaHSO}_4) - (\Delta H_f \text{ NaNO}_3 + \Delta H_f \text{ H}_2\text{SO}_4)$$

$$= (-41,404 - 269,20) - (-101,54 - 193,91)$$

$$= - 15,154 \text{ kkal/mol}$$

$$= -15154 \text{ Kkal/kmol}$$

NaNO₃ yang bereaksi 10,6678616 kmol (perhitungan neraca massa)

$$\text{Maka panas reaksi} = 10,6678616 \text{ kmol} \times -15154 \text{ Kkal/kmol}$$

$$= - 161660.77469 \text{ kkal}$$

$$\Delta HR_{150^\circ\text{C}} = \Delta HR_{25^\circ\text{C}} + \sum \text{cpdt produk} - \sum \text{cpdt reaktan}$$

$$= -161660.77469 \text{ kkal} + (504865,0479) - (291141,6171)$$

$$= 52062,65611 \text{ kkal}$$

$$\text{Panas masuk} = Q_{\text{bahan baku}} + \Delta HR_{150^\circ\text{C}}$$

$$= 291141,6171 \text{ kkal} + 52062,65611 \text{ kkal}$$

$$= 343204,2732 \text{ kkal}$$

$$\text{Panas keluar} = Q_{\text{uap hasil}} + Q_{\text{either cake}}$$

$$= 204162,8566 \text{ Kkal} + 300702,1913 \text{ Kkal}$$

$$= 504865,0479 \text{ Kkal}$$

Maka kebutuhan steam pemanas = panas keluar – panas masuk

$$= 504865,0479 \text{ Kkal} - 343204,2732 \text{ Kkal}$$

$$= 161660,7747 \text{ Kkal}$$

Neraca panas secara lengkap

Tabel 6. 1 neraca panas reaktor

Panas masuk		Panas keluar	
Komponen	Q (kkal)	Komponen	Q (kkal)
Bahan baku	291141,6171	Uap	204162,8566
Panas reaksi	52062,65611	Either cake	300702,1913
Steam pemanas	161660,77469		
	504865,0479		504856,0476

Kondisi operasi reaktor:

$$P = 1 \text{ atm} = 101,325 \text{ Kpa}$$

$$T = 150^{\circ}\text{C} = 423^{\circ}\text{K}$$

Maka steam yang digunakan adalah

Saturated steam pada 200°C . $P = 618,06 \text{ Kpa}$.

$$\lambda = 2790,9 \text{ Kj/kg} = 666,46692 \text{ Kkal/kg}$$

$$M = \frac{Q}{\lambda} = \frac{161660,7747 \text{ Kkal}}{666,46692 \text{ Kkal/kg}}$$

$$M = 242,5638 \text{ kg}$$

1.2 Neraca Panas Condensor

a. Panas bahan masuk :

Suhu masuk : 150°C

Suhu ref = 25°C

Komponen	m (kg)	n (kmol)	Cp (Kkal/kmol)	Q (Kkal)
HNO ₃	672,075277	10,6678615	1495,9841	159591,0389
H ₂ O	84,7270158	4,70705644	946,914878	44571,8177
				204162,8566

b. Panas bahan keluar

Suhu keluar : 95°C

Suhu ref = 25°C

A. Uap

Komponen	Berat (kg)	Kmol	Cp dT	Q
HNO ₃	324,9698	5,15825143	800,173832	41274,9781
H ₂ O	5,9852	0,32511666	527,046871	1752,49233
NO ₂	49,0721	1,06678608	64,1008145	683,81857
O ₂	8,5343	0,266696562	52,3209934	166,207947
				43877,49698

B. Cair

Komponen	Berat (kg)	kmol	Cp dT	Q
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HNO ₃	279,89812	4.44282730	800,173832	35550,34148
H ₂ O	88,34326	4,90795889	527,046871	25867,24377
				61417,58525

Total panas keluar kondensor

$$\begin{aligned}
 Q_{\text{out}} &= Q_{\text{uap}} - Q_{\text{Hv}} \\
 &= 204162,8566 - 61417,58525 \\
 &= 105295,0882 \text{ kkal}
 \end{aligned}$$

Panas pengembunan uap:

Komponen	Berat (kg)	kmol	Hv (Kkal/kmol)	Q
HNO ₃	604,8677	9,60107444	970,87	93213,9514
H ₂ O	94,3282	5,24045555	1006,556	52748,1355
				145962,087

$$\begin{aligned}
 \text{Panas masuk kondensor} &= Q_{\text{masuk}} + Q_{\text{Hv}} \\
 &= 204162,8566 + 145962,087 \\
 &= 350124,944 \text{ kkal}
 \end{aligned}$$

$$\begin{aligned}
 \text{Beban panas} &= 350124,944 \text{ kkal} - 105295,0882 \text{ kkal} \\
 &= 244829,861 \text{ kkal}
 \end{aligned}$$

Tabel 6. 2 Neraca panas condensor

Panas masuk	Panas keluar
-------------	--------------

Komponen	Q (kkal)	Komponen	Q (kkal)
Panas masuk	204162,8566	Panas keluar	105295,0882
Panas penguapan	145962,087	Pendingin	244829,861
	350124,94		350124,94

Menentukan jumlah air pendingin :

Suhu pendingin masuk = 30° C

Suhu pendingin keluar = 40° C

Cp pendingin = 1 Kcal/kg.°C

Jumlah pendingin :

$$\begin{aligned}
 M &= \frac{Q_c}{C_p \cdot (t_2 - t_1)} \\
 &= \frac{244829,861}{1 \cdot (40 - 30)} \\
 &= 24482,9861 \text{ kg/jam}
 \end{aligned}$$

1.3 Neraca Panas Separator

Bahan masuk :

a. Uap dari condensor

Suhu keluar : 95°C

Suhu ref = 25°C

Komponen	Berat (kg)	Kmol	Cp dT	Q
HNO ₃	324,9698	5,15825143	800,173832	41274,9781

H ₂ O	5,9852	0,32511666	527,046871	1752,49233
NO ₂	49,0721	1,06678608	64,1008145	683,81857
O ₂	8,5343	0,266696562	52,3209934	166,207947
				43877,49698

b. Cairan dari kondensor

Suhu keluar : 95°C

Suhu ref = 25°C

Komponen	Berat (kg)	kmol	Cp dT	Q
HNO ₃	279,89812	4.44282730	800,173832	35550,34148
H ₂ O	88,34326	4,90795889	527,046871	25867,24377
				61417,58525

Bahan keluar kondensor

Suhu keluar : 95°C

Suhu ref = 25°C

Komponen	Berat (kg)	Kmol	Cp (kkal/kmol)	Q
NO ₂	49,07216	1,066786087	64,1008145	683,81857
O ₂	8,5343	0,266696562	62,3209935	166,207947
HNO ₃	324,96984	5,15825143	800,173832	41274,9781
H ₂ O	5,98521	3,32511667	527,046871	1752,492336

HNO ₃	604,86769	9,60107444	800,173832	27619,65705
H ₂ O	94,3238	5,24045556	527,046871	105294,9689
				105294,9689

Neraca panas secara lengkap

Tabel 6. 3 Neraca Panas Separator

Panas masuk		Panas keluar	
Komponen	Q (kkal)	Komponen	Q (kkal)
Uap	43877,49698	Panas keluar	105294,9689
Cairan	61417,58525		
	105294,9689		105294,9689

1.4 Neraca Panas Absorber

Bahan masuk

- a. Uap dari sparator

Uap masuk pada suhu 50°C

Komponen	Berat (kg)	Kmol	Cp dT	Q
HNO ₃	324,9698425	5,158251468	278,7119425	14376,66287
H ₂ O	5,985605143	0,332533619	188,3080946	626,187722
O ₂	49,07216313	1,533505098	22,40868893	334,95424
NO ₂	8,53428924	0,185528027	18,24129524	41,57439843

				15379,37923
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b. Air make up

Suhu masuk: 30°C

Jumlah air absorben : 1,8819 kg = 0,10455 kmol

Cp air (30°C) = 89,88161 kkal/kmol k

$$Q = (0,10455)(89,88161)$$

$$= 9,397322 \text{ kkal}$$

Bahan keluar

Suhu keluar absorber 43,49°C

a. Cair

Komponen	Berat (kg)	Kmol	Cp dT	Q
HNO ₃	33,5,1386	5,31966038	205,6569	10940,2503
H ₂ O	180,4593	10,02551667	139,3639	13971,9495
				24912,1998

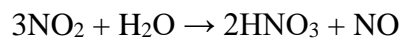
b. Uap

Komponen	Berat (kg)	Kmol	Cp dT	Q
NO ₂	0,853429	0,0185528	16,52304	3,065489
NO	0,166975	0,0055658	13,48579	0,750597
O ₂	47,86994	1,49593569	16,11312	241,04194

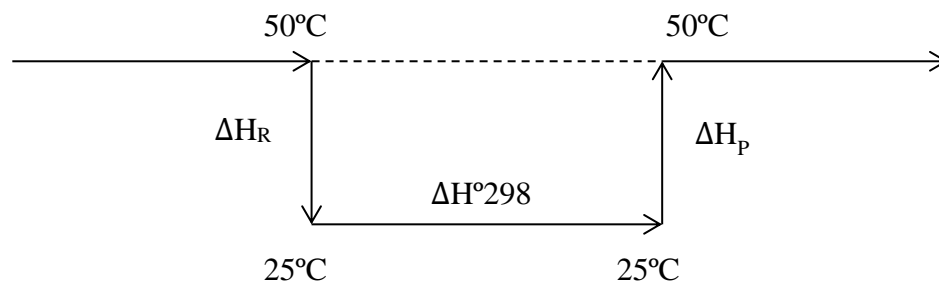
				244,858026
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Panas reaksi

Reaksi:



Profil suhu reaksi



$$\Delta H_{f(298)} \text{HNO}_3 : -41,404$$

$$\Delta H_{f(298)} \text{NO}_2 : 8,041$$

$$\Delta H_{f(298)} \text{H}_2\text{O} : -68,317$$

$$\Delta H_{f(298)} \text{NO} : 21,6 \text{ Kcal/gmol (Van Ness)}$$

$$\Delta H_{(298)} = (2\Delta H_f \text{HNO}_3 + \Delta H_f \text{NO}) - (3\Delta H_f \text{NO}_2 + \Delta H_f \text{H}_2\text{O})$$

$$= (2.(-41,404) + 21,6) - (3.(8,041) - 68,317)$$

$$= -61,202 - (-44,194)$$

$$= -17,008 \text{ kkal/mol}$$

$$= -17008 \text{ kkal/kmol}$$

NO₂ reaksi = 0.166975 kmol (perhitungan neraca massa)

Maka $\Delta H_{(298)} = 0,166975 \text{ kmol} \times (-17008 \text{ kkal/kmol})$

$$= -2839,9108 \text{ kkal}$$

Reaktan

Komponen	Berat (kg)	Kmol	Cp dT	Q
NO ₂	7,68086032	0,166975224	16,52304058	27,58938402
H ₂ O	1,00185135	0,0556658408	139,3638846	77,56771951
				105,1571035

Produk

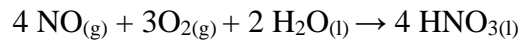
Komponen	Berat (kg)	Kmol	Cp dT	Q
NO	1,6697522	0,055658408	13,485789	7,5059769
HNO ₃	7,0129594	0,111316816	205,656933	228,93075
				236,4367259

$$\Delta H_{\text{reaksi}} = \Delta H_{(298)} + \sum \text{cpdt produk} - \sum \text{cpdt reaktan}$$

$$= -2839,9108 \text{ kkal} + 236,4367259 - [105,1571035]$$

$$= -2708,631178 \text{ kkal}$$

Reaksi 2:



$$\begin{aligned} \Delta H_{(298)} &= (4\Delta H_f \text{HNO}_3) - (4\Delta H_f \text{O}_2 + 2\Delta H_f \text{H}_2\text{O}) \\ &= (4 \cdot (-41,401)) - (4(21,6) + 3 \cdot (0) + 2(-68,317)) \\ &= (-165,604) - (86,4 + 0 + (-136,634)) \\ &= -115,370 \text{ kkal/mol} = -115370 \text{ kkal/kmol} \end{aligned}$$

NO reaksi 0,5009 kmol

$$\begin{aligned} \text{Maka panas reaksi} &= 0,05009 \times -115370 \\ &= -5778,8833 \text{ kkal} \end{aligned}$$

Reaktan

Komponen	Berat (kg)	Kmol	Cp dT	Q
NO	1,502777018	0,050092567	13,48578941	6,755031917
O ₂	1,20222161	0,037569	16,11312193	6,053538779
H ₂ O	0,4508333106	0,02504	139,3638846	34,89671671
				47,70528741

Produk

Komponen	Berat (kg)	Kmol	Cp dT	Q
HNO ₃	3,15583174	0,05009	205,6569335	103,013558

$$\begin{aligned} \Delta H_{\text{reaksi}} &= \Delta H_{(298)} + \sum \text{cpdt produk} - \sum \text{cpdt reaktan} \\ &= -5778,8833 + 103,013558 - 47,70528741 \end{aligned}$$

$$= -5723,575029 \text{ kkal}$$

$$\text{Maka jumlah reaksi} = -2708,631178 \text{ kkal} - 5723,575029 \text{ kkal}$$

$$= -8432,206207 \text{ kkal}$$

Panas masuk

$$- \text{ Uap dari separator} = 15379,37923$$

$$- \text{ Absorben (H}_2\text{O)} = 9,397322$$

$$- \text{ Panas reaksi} = \underline{8432,206207} +$$

$$23820,98276 \text{ kkal}$$

Panas keluar

$$- \text{ Uap keluar} = 244,858026$$

$$- \text{ Cairan hasil} = \underline{24912,19976} +$$

$$25157,0578 \text{ kkal}$$

$$\text{Beban panas pada absorber} = 25157,0578 \text{ kkal} - 23820,98276 \text{ kkal}$$

$$= 1336,075027 \text{ kkal}$$

Neraca massa secara lengkap

Tabel 6. 4 Neraca Panas Absorber

Panas masuk		Panas keluar	
Komponen	Q (kkal)	Komponen	Q (kkal)
Uap masuk	15379,37923	Uap	244,858026
Absorben	9,397322	Cair	24912,19976

Reaksi	8432,206207		
Beban panas	1336,075027		
	25157,0578		25157,0578