APPENDIKS A
PERHITUNGAN NERACA MASSA

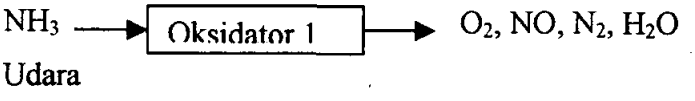
Kapasitas : 15.000 ton/tahun

Basis fasa : NH_3 gas

Udara gas

Suhu refrensi : 25°C

1. OKSIDATOR 1 (R-210)



Dari Ullman vol.A.17

Reaksi : $NH3\ (g) + \frac{5}{4} O2\ (g) \longrightarrow NO\ (g) + \frac{3}{2} H2O\ (g)$ (96%)

$NH3\ (g) + \frac{3}{4} O2\ (g) \longrightarrow \frac{1}{2} N2\ (g) + \frac{3}{2} H2O\ (g)$ (4%)

NH3 masuk dengan kadar 99,5 % = 428,9937 kg/jam

NH3 = 0,995 x 428,9937 = 426,8487 kg/jam

H2O = 0,005 x 428,9937 = 2,1450 kg/jam

Udara masuk dianggap 60% jenuh

humidity = 0,0175 kg H2O/kg udara kering

Udara masuk = 7681,9666 kg/jam

$$H2O = \frac{0,0175}{0,0175+1} \text{ x } 7681,9666 = 132,1223 \text{ kg/jam}$$

$$N2 = 0,79 \text{ x } \frac{7681,9666 - 132,1223}{28,84} \text{ x } 28 = 5790,6573 \text{ kg/jam}$$

$$O2 = 0,21 \text{ x } \frac{7681,9666 - 132,1223}{28,84} \text{ x } 32 = 1759,1870 \text{ kg/jam}$$

Reaksi (1)

NH3 mula-mula = 25,1087 kmol/jam

NH3 yang bereaksi = 0,96 x 25,1087 = 24,1044 kmol/jam

NH3 sisa = 25,1087 – 24,1044 = 1,0043 kmol/jam

O2 mula-mula = 54,9746 kmol/jam

O2 bereaksi = $\frac{5}{4}$ x 24,1044 = 30,1305 kmol/jam

O2 sisa = 54,9746 – 30,1305 = 24,8441 kmol/jam

NO hasil = 24,1044 kmol/jam

H2O hasil = $\frac{3}{2}$ x 24,1044 = 36,1566 kmol/jam

Reaksi (2)

NH3 bereaksi = 1,0043 kmol/jam

O2 bereaksi = $\frac{3}{4}$ x 1,0043 = 0,7533 kmol/jam

O2 sisa = 24,8441 – 0,7533 = 24,0908 kmol/jam

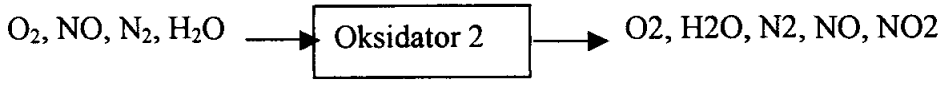
N2 hasil = $\frac{1}{2}$ x 1,0043 = 0,5022 kmol/jam

H2O hasil = $\frac{3}{2}$ x 1,0043 = 1,5065 kmol/jam

Neraca massa pada oksidator 1 :

Masuk, kg/jam		Keluar, kg/jam	
O2	1759,1870	O2	770,9067
N2	5790,6573	N2	5804,7182
H2O	134,2672	H2O	812,2035
NH3	426,8487	NO	723,1320
Total =	8110,9603	Total =	8110,9603

2. OKSIDATOR 2 (R-230)



Reaksi : $NO\,(g) + \frac{1}{2} O2\,(g) \longrightarrow NO2\,(g)$ (95%)

Dari recycle diperoleh :

O2 = 324,8375 kg/jam

N2 = 5804,7182 kg/jam

NO = 158,3967 kg/jam

NO2 = 32,8833 kg/jam

Gas masuk oksidator 2 :

O2 = 770,9067 + 324,8375 = 1095,7442 kg/jam = 34,2420 kmol/jam

N2 = 5804,7182 + 5804,7182 = 11609,4364 kg/jam

H2O = 812,2035 kg/jam

NO = 158,3967 + 723,1320 = 881,5287 kg/jam = 29,3843 kmol/jam

NO2 = 32,8833 kg/jam

NO yang bereaksi = 0,95 x 29,3843 = 27,9151 kmol/jam

NO sisa = 29,3843 – 27,9151 = 1,4692 kmol/jam = 44,0764 kg/jam

O2 bereaksi = $\frac{1}{2}$ x 27,9151 = 13,9575 kmol/jam

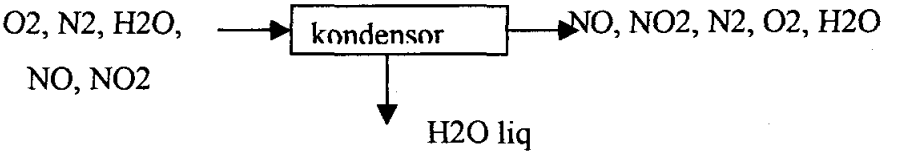
O2 sisa = 34,2420 – 13,9575 = 20,2845 kmol/jam = 649,1030 kg/jam

NO2 hasil = 27,9151 kmol/jam = 1316,9767 kg/jam

Neraca massa pada oksidator 2 :

Masuk, kg/jam		Keluar, kg/jam	
O2	1095,7442	O2	649,1030
N2	11609,4364	N2	11609,4364
H2O	812,2035	H2O	812,2035
NO	881,5287	NO	44,0764
NO2	32,8833	NO2	1316,9767
Total =	14431,7960	Total =	14431,7960

3. KONDENSOR (E-212)



Suhu keluar kondensor = 35°C

Jumlah gas-gas masuk = 14431,7980 kg/jam

Tekanan uap air pada suhu 35°C = 42,1750 mmHg = 0,055 atm

$$\frac{x}{G-x} = \frac{P}{P_{total}}$$

$$\frac{x}{14431{,}7980 - x} = \frac{0{,}055}{9{,}37}$$

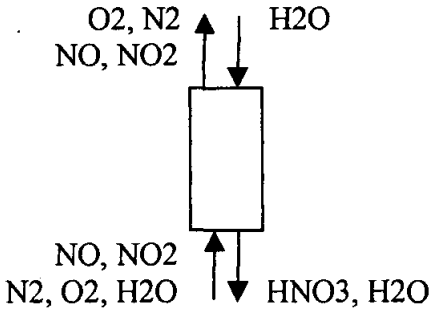
H2O yang terikut dalam gas keluar kondensor (x) = 84,9785 kg/jam

H2O yang mengembun = 812,2035 – 84,9785 = 727,2250 kg/jam

Neraca massa pada kondensor :

Masuk, kg/jam		Keluar, kg/jam	
		Bagian atas :	
O2	1095,7442	O2	649,1030
N2	11609,4364	N2	11609,4364
H2O	812,2035	H2O	84,9785
NO	881,5287	NO	44,0764
NO2	32,8833	NO2	1316,9767
		Bagian bawah :	
		H2O liq	727,2250
Total =	14431,7960	Total =	14431,7960

4. ABSORBER (D-240)



Reaksi : 3 NO2 (g) + H2O(l) ⟶ 2 HNO3 (l) + NO (g) (95%)

NO2 masuk = 1316,9767 kg/jam = 28,6299 kmol/jam

NO2 bereaksi = 0,95 x 28,6299 = 27,1984 kmol/jam

NO2 sisa = 28.6299 – 27,1984 = 1,4315 kmol/jam

$$\text{H2O bereaksi} = \frac{1}{3} \text{x } 27{,}1984 = 9{,}0661 \text{ kmol/jam}$$

$$\text{HNO3 hasil} = \frac{2}{3} \text{x } 27{,}1984 = 18{,}1323 \text{ kmol/jam}$$

NO keluar absorber = 9,0661 + 1,4692 = 10,5354 kmol/jam = 316,0608 kg/jam

Untuk menghasilkan HNO3 60% maka H2O yang ditambahkan

= 839,7682 kg/jam

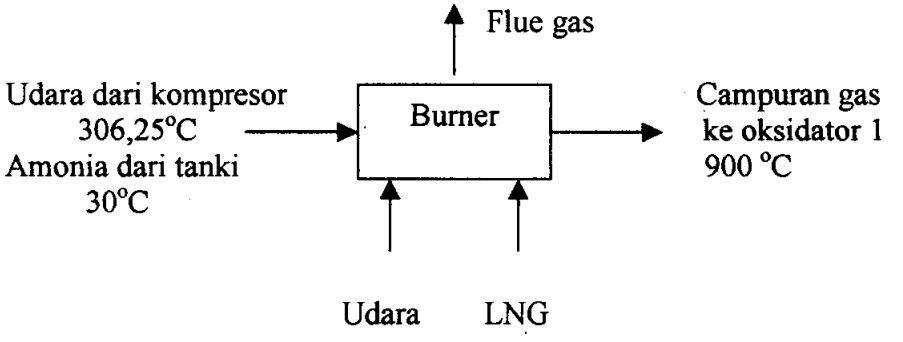
Neraca massa pada absorber :

Masuk, kg/jam		Keluar, kg/jam	
Bagian atas:		Bagian atas :	
H2O	839,7682	O2	649,1030
Bagian bawah:		N2	11609,4364
N2	11609,4364	NO	316,0608
NO	44,0764	NO2	65,8488
NO2	1316,9767	Bagian bawah:	
O2	649,1030	HNO3	1142,3342
H2O	84,9785	H2O	727,2250
Total =	14544,3392	Total =	14544,3392

APPENDIKS B

PERHITUNGAN NERACA PANAS

Burner (Q – 211)



Bahan bakar yang digunakan LNG dengan komposisi :

metana = 87,1 %

etana = 3,41 %

propana = 1,73 %

N_2 = 7,1 %

CO_2 = 0,31 %

Helium = 0,35 %

Dari Perry ed. 7 :

Heating value = 86000 Btu / gal

<u>Panas bahan masuk :</u>

Tekanan pada burner = 9,86 atm

Suhu amonia masuk = 30 °C

$$T = \frac{30 + 25}{2} = 27{,}5\ ^\circ C = 81{,}5\ ^\circ F$$

Massa NH_3 masuk = 426,8487 kg / jam = 25,1087 kmol/jam

Massa H_2O masuk = 2,1450 kg / jam = 0,1192 kmol/jam

Dari Kern fig. 3 :

Cp NH_3 = 0,52 Btu / lb °F = 0,52 kkal / kg °C

Cp H_2O = 0,44 Btu / lb °F = 0,44 kkal / kg °C

$H_{ig\ NH3}$ = m * Cp * ΔT = 426,8487 * 0,52 * (30 - 25) = 1109,8066 kkal

$H_{ig\ H2O}$ = m * Cp * ΔT = 22,2553 * 0,44 * (30 - 25) = 48,9617 kkal

Dari Smith Van Ness app.B

Tc NH3 = 405,7 K

Pc NH3 = 112,8 atm

ω NH3 = 0,253

Tc H2O = 647,1 K

Pc H2O = 220,5 atm

ω H2O = 0,345

$$\text{Tr NH3} = \frac{30+273}{405,7} = 0,7469$$

$$\text{Tr H2O} = \frac{30+273}{647,1} = 0,4682$$

$$\text{Pr NH3} = \frac{9.86}{112,8} = 0,0874$$

$$\text{Pr H2O} = \frac{9,86}{220,5} = 0,0447$$

Dari Smith Van Ness app B:

$$\left(\frac{(H^R)^0}{RT_c}\right)_{NH3} = -0,1607$$

$$\left(\frac{(H^R)^0}{RT_c}\right)_{H2O} = -5,5581$$

$$\left(\frac{(H^R)^1}{RT_c}\right)_{NH3} = -0,2704$$

$$\left(\frac{(H^R)^1}{RT_c}\right)_{H2O} = -8,6339$$

$$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega.\frac{(H^R)^1}{RT_c}\right).\ R.\ T_c$$

$(H^R)_{NH3}$ = ((-0,1607 + 0,253. (–0,2704)). 8,314 . 405,7) / 4,2

= -183,9976 kkal/kmol

= -183,9976 kkal/kmol x 25,1087 kmol = - 4619,9485 kkal

$(H^R)_{H2O}$ = ((-5,5581 + 0,345. (–8,6339)). 8,314 . 647,1) / 4,2

= -10935,2070 kkal/kmol

= -10935,2070 kkal/kmol x 0,1192 kmol = -1303,0930 kkal

$H_{NH3} = H_{igNH3} + (H^R)_{NH3}$ = 1109,8067 + -4619,9485 = -3510,1418 kkal

$H_{H2O} = H_{igH2O} + (H^R)_{H2O}$ = 4,7189 + -1303,0903 = -1298,3741 kkal

Udara masuk pada suhu = 306,25°C

Suhu rata-rata = (306,25 + 25)/ 2 = 185,62°C

Massa N2 masuk = 5790,6573 kg / jam = 206,8092 kmol/jam

Massa O2 masuk = 1759,1870 kg/jam = 54,9746 kmol/jam

Massa H_2O masuk = 132,1223 kg / jam = 7,3401 kmol/jam

Dari Kern fig. 3 :

Cp N2 = 0,26 Btu / lb °F = 0,26 kkal / kg °C

Cp O2 = 0,23 Btu / lb °F = 0,23 kkal / kg °C

Cp H_2O = 0,46 Btu / lb °F = 0,46 kkal / kg °C

$H_{ig\ N2}$ = m * Cp * ΔT = 5790,6573 * 0,26 * (306,25 - 25)= 423435,6523 kkal

$H_{ig\ O2}$ = m * Cp * ΔT = 1759,1870 * 0,23 * (306,25 - 25)= 113795,7547 kkal

$H_{ig\ H2O}$ = m * Cp * ΔT = 132,1223 * 0,46 * (306,25 - 25)= 17093,0706 kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K Tc H2O = 647,1 K

Pc N2 = 34 atm Pc H2O = 220,5 atm

ω NH2 = 0,0,038

ω H2O = 0,345

Tc O2 = 154,6 K

Pc O2 = 50,43 atm

ω O2 = 0,022

$$\text{Tr N2} = \frac{306,25+273}{126,2} = 4,5899$$

$$\text{Tr H2O} = \frac{306,25+273}{647,1} = 0,8951$$

$$\text{Pr N2} = \frac{9.86}{34} = 0,29$$

$$\text{Pr H2O} = \frac{9,86}{220,5} = 0,0447$$

$$\text{Tr O2} = \frac{306,25+273}{154,6} = 3,7467$$

$$\text{Pr O2} = \frac{9.86}{50,43} = 0,1955$$

Dari Smith Van Ness app B:

$$\frac{(H^R)^0}{RT_c}_{N2} = -0,0023$$

$$\frac{(H^R)^0}{RT_c}_{H2O} = -0,0533$$

$$\frac{(H^R)^1}{RT_c}_{N2} = 0,0237$$

$$\frac{(H^R)^1}{RT_c}_{H2O} = -0,0641$$

$$\frac{(H^R)^0}{RT_c}_{O2} = -0,0018$$

$$\frac{(H^R)^1}{RT_c}_{O2} = 0,0308$$

$$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right) . R . T_c$$

$$(H^R)_{N2} = ((-0,0023 + 0,038 . 0,0237) . 8,314 . 126,2) / 4,2$$

$$= -0,3496 \text{ kkal/kmol}$$

= -0,3496 kkal/kmol x 206,6092 kmol = -72,2989 kkal

$(H^R)_{O2}$ = ((-0,0118 + 0,022. 0,0308). 8,314 . 154,6) / 4,2

= -3,4038 kkal/kmol

= -3,4038 kkal/kmol x 54,9746 kmol = -187,1245 kkal

$(H^R)_{H2O}$ = ((-0,0533 + 0,345. (–0,0641)). 8,314 . 647,1) / 4,2

= -96,6022 kkal/kmol

= -96,6022 kkal/kmol x 7,3401 kmol = -709,0723 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2}$ = 423435,6523 + -72,2989 = 423363,3534 kkal

$H_{O2} = H_{igO2} + (H^R)_{O2}$ = 113795,7547 + -187,1245 = 113608,6301 kkal

$H_{H2O} = H_{igH2O} + (H^R)_{H2O}$ = 17093,0706 + -96,6022 = 16383,9983 kkal

Panas bahan masuk:

H_{N2} = 423363,3534 kkal

H_{O2} = 113608,6301 kkal

H_{H2O} = 16383,9983 kkal

H_{NH3} = -3510,1418 kkal

H_{H2O} = -1298,3741 kkal

548547,4660 kkal

Panas bahan keluar :

Suhu gas keluar = 900 °C

$$T = \frac{900 + 25}{2} = 864{,}5 \text{ °F}$$

Dari Kern fig. 3 :

Cp NH_3 = 0,59 Btu / lb °F = 0,59 kkal / kg °C

Cp H_2O = 0,47 Btu / lb °F = 0,47 kkal / kg °C

Cp N_2 = 0,26 Btu / lb °F = 0,26 kkal / kg °C

Cp O_2 = 0,235 Btu / lb °F = 0,235 kkal / kg °C

H_{igNH3} = m * Cp * ΔT = 426,8487 * 0,59 * (900 - 25) = 220360,6576 kkal

H_{igH2O} = m * Cp * ΔT = 134,2672 * 0,47 * (900 - 25) = 55217,4042 kkal

H_{igN2} = m * Cp * ΔT = 5790,6573 * 0,26 * (900 - 25) = 1317374,5351 kkal

H_{igO2} = m * Cp * ΔT = 1759,1870 * 0,235 * (900 - 25) = 361732,8324 kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K

Pc N2 = 34 atm

ω N2 = 0,0,038

Tc O2 = 154,6 K

Pc O2 = 50,43 atm

ω O2 = 0,022

$$\text{Tr N2} = \frac{900+273}{126,2} = 9,2948$$

$$\text{Pr N2} = \frac{9.86}{34} = 0,29$$

$$\text{Tr O2} = \frac{900+273}{154,6} = 7,5873$$

$$\text{Pr O2} = \frac{9.86}{50,43} = 0,1955$$

Tc H2O = 647,1 K

Pc H2O = 220,5 atm

ω H2O = 0,345

Tc NH3 = 405,7 K

Pc NH3 = 112,8 atm

ω NH3 = 0,253

$$\text{Tr H2O} = \frac{900+273}{647,1} = 1,8127$$

$$\text{Pr H2O} = \frac{9,86}{220,5} = 0,0447$$

$$\text{Tr NH3} = \frac{900+273}{154,6} = 2,8913$$

$$\text{Pr NH3} = \frac{9.86}{50,43} = 0,195$$

Dari Smith Van Ness app B:

$\frac{(H^R)^0}{RT_c}_{N2} = 0,0039$ $\frac{(H^R)^0}{RT_c}_{H2O} = -0,0149$

$\frac{(H^R)^1}{RT_c}_{N2} = 0,0419$ $\frac{(H^R)^1}{RT_c}_{H2O} = 0,0011$

$\frac{(H^R)^0}{RT_c}_{O2} = -0,0007$ $\frac{(H^R)^0}{RT_c}_{NH3} = -0,0066$

$\frac{(H^R)^1}{RT_c}_{O2} = 0,0385$ $\frac{(H^R)^1}{RT_c}_{NH3} = 0,0122$

$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right)$. R. T_c

$(H^R)_{N2}$ = ((0,0039 + (0,038. 0,0419)). 8,314 . 126,2) / 4,2

= 1,3720 kkal/kmol

= 1,3720 kkal/kmol x 206,6092 kmol = 7945,0071 kkal

$(H^R)_{O2}$ = ((-0,0007 + (0,022. 0,0385)). 8,314 . 154,6) / 4,2

= 0,045 kkal/kmol

= 0,045 kkal/kmol x 54,9746 kmol = 2,4731 kkal

$(H^R)_{H2O}$ = ((-0,0149 + (0,345. 0,0011)). 8,314 . 647,1) / 4,2

= -18,60 kkal/kmol

= -18,60 kkal/kmol x 7,3401 kmol = -138,7431 kkal

$(H^R)_{NH3}$ = ((-0,0066 + (0,253. 0,0122)). 8,314 . 647,1) / 4,2

= -4,4278 kkal/kmol

= -4,4278 kkal/kmol x 25,1087 kmol = -111,1758 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2}$ = 1317374,5351 + 7945,0071 = 1325319,5423 kkal

$H_{O2} = H_{igO2} + (H^R)_{O2} = 361732,8324 + 2,4731 = 361735,3056$ kkal

$H_{H2O} = H_{igH2O} + (H^R)_{H2O} = 55217,4042 + -138,7431 = 55078,6611$ kkal

$H_{NH3} = H_{igNH3} + (H^R)_{NH3} = 220360,6576 + -111,1758 = 220249,4818$ kkal

1962382,9908 kkal

Panas yang dibutuhkan = panas keluar – panas masuk

= 1962382,9908 – 548547,4660

= 1413835,5248 kkal / jam

Reaksi yang terjadi : $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$ (1)

$C_2H_6 + \frac{7}{2} O_2 \longrightarrow 2CO_2 + 3H_2O$ (2)

$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$ (3)

Kebutuhan O_2 :

Reaksi 1 :

O_2 yang bereaksi = 2 * 0,0544 x kmol

CO_2 hasil = 0,0544 x kmol

H_2O hasil = 0,1088 x kmol

Reaksi 2 :

O_2 yang beraksi = $\frac{7}{2} * 1,1367.10^{-3} = 3,9785.10^{-3} x$ kmol

CO_2 hasil = 2 * $1,1367.10^{-3}$ x = $2,2734.10^{-3}$x kmol

H_2O hasil = 3 * $1,1367.10^{-3}$ x = $3,4101.10^{-3}$x kmol

Reaksi 3 :

O_2 yang bereaksi = 5 * $3,9318.10^{-4}$ x = $1,9659.10^{-3}$x kmol

CO_2 hasil = 3 * $3,9318.10^{-4}$ x = $1,1795.10^{-3}$x kmol

H_2O hasil = 4 * 3,9318.10^{-4}x = 1,3567.10^{-3}x kmol

Kebutuhan O_2 = 0,1088 + 3,9785.10^{-3} + 1,9659.10^{-3} = 0,1147 x kmol

O_2 yang ditambahkan 15 % berlebih = 1,15 * 0,1147 x = 0,1319 x kmol

= 4,2226 x kg / jam

N_2 yang masuk = $\frac{79}{21}$ * 4,2226x = 0,4392x kmol = 13,8935 x kg / jam

O_2 sisa = 0,1319 x – 0,1147 x = 0,0172 x kmol

CO_2 hasil = 0,0544 x + 2,2734.10^{-3}x + 1,1795.10^{-2}x + 7,0455.10^{-5}x

= 0,0685 x kmol

H_2O hasil = 0,1088 + 3,4101.10^{-3}x + 1,3567.10^{-3}x = 0,1136 x kmol

Kebutuhan bahan bakar :

Basis kebutuhan bahan bakar = x kg

CH_4 = 87,1 % = 0,871x kg = 0,0544 x kmol

C_2H_4= 3,41 % = 0,341x kg = 1,1367.10^{-3} x kmol

C_3H_6= 1,73 % = 0,00173x kg = 3,9318.10^{-4} x kmol

N_2 = 7,1 % = 0,0071x kg = 2,5357.10^{-3} x kmol

CO_2 = 0,31 % = 0,0031x kg = 7,0455.10^{-5} x kmol

He = 0,35 % = 0,0035x kg = 8,75.10^{-4} x kmol

Panas yang dihasilkan :

1. Bahan bakar

   Suhu bahan bakar masuk = 30 °C = 303 °K

   T = $\frac{303 + 298}{2}$ = 300,5 °K

Dari Kern, fig.5 :

Cp CH_4 = 0,852 kkal / kg °C

Cp C_2H_6 = 0,65 kkal / kg °C

Cp C_3H_6 = 0,45 kkal / kg °C

Cp N_2 = 0,255 kkal / kg °C

Cp CO_2 = 0,21 kkal / kg °C

Dari Perry, ed.7, tab.2-194

Cp He = 4,97 kkal / kmol °C

H_{CH4} = m * Cp * ΔT = 0,871x * 0,852 * (900-25) = 3,7105 x kkal

H_{C2H6} = m * Cp * ΔT = 0,0341 x * 0,65 * (900-25) = 0,1108 x kkal

H_{C3H6} = m * Cp * ΔT = 0,0173 x * 0,45 * (900-25) = 0,0389 x kkal

H_{N2} = m * Cp * ΔT = 0,071 x * 0,255 * (900-25) = 0,0905 x kkal

H_{CO2} = m * Cp * ΔT = 0,0031 x * 0,21 * (900-25) = 0,0032 x kkal

H_{He} = m * Cp * ΔT = $8,75.10^{-4}$ x * 4,97 * (900-25) = 0,0217 x kkal

Panas bahan bakar total = 2,7962 x kkal

2. Panas udara

Suhu udara masuk = 30 °C = 303 °K

$$T = \frac{303 + 298}{2} = 300,5 \text{ °K}$$

Dari Perry ed. 6 tab. 3 -181 :

Cp O_2 = 6,269 kkal / kmol °K

Cp N_2 = 6,801 kkal / kmol °K

H_{O2} = m * Cp * ΔT = 0,1319 x * 6,269 * (303-298) = 4,1344 x kkal

H_{N2} = m * Cp * ΔT = 0,4962 x * 6,801 * (303-298) = 16,8733 x kkal

= 21,0077 x kkal

3. Panas Pembakaran

Heating value = 86000 Btu / gal

ρ = 3,4469 lb/gal

$$Hv = \frac{86000}{3,4469} = 24949,45 \text{ btu/lb} = 13869,9122 \text{ kkal/kg}$$

H = m * H_v = x * 13869,9122 = 13869,9122 x kkal

Menghitung panas flue gas keluar :

CO_2 = 0,0685 x kmol = 3,014 x kg

H_2O = 0,1136 x kmol = 2,0448 x kg

He = $8,75.10^{-4}$ x kmol

O_2 = 0,0172 x kmol

N_2 = 0,4962 x + $2,535.10^{-5}$ x = 0,4962 x kmol = 13,8936 x kmol

Suhu flue gas keluar = 1200 °C = 1473 °K

$$T = \frac{1473 + 298}{2} = 885,5 \text{ °K}$$

Dari Kern, fig.3 :

Cp CO_2 = 0,29 kkal / kg °C

Cp H_2O = 0,5 kkal / kg °C

Cp O_2 = 0,25 kkal / kg °C

Cp N_2 = 0,265 kkal / kg °C

Dari Perry, ed.7. tab.2-194 :

Cp He = 4,97 kkal / kmol °C

H_{CO2} = m * Cp * ΔT = 3,014 x * 0,29 * (1200-25) = 1027,0205 x kkal

H_{H2O} = m * Cp * ΔT = 2,0448 x * 0,5 * (1200-25) = 1201,3200 x kkal

H_{O2} = m * Cp * ΔT = 0,5504 x * 0.25 * (1200-25) = 161,6800 x kkal

H_{N2} = m * Cp * ΔT = 13,8936 x * 0,265 * (1200-25) = 4326,1190 x kkal

H_{He} = m * Cp * ΔT = $8,75.10^{-4}$ x * 4,97 * (1200-25) = 5,1098 x kkal

= 6721,2493 x kkal

Panas yang hilang = 20 % dari panas pembakaran

= 0,2 * 13869,9122 x

= 2773,9824 x kkal

Panas masuk :

Panas bahan = 548547,4660 kkal

Panas bahan bakar = 3,9756 x kkal

Panas pembakaran = 13869,9122 x kkal

Panas udara = 21,0077 x kkal

= (548547,4660 + 13894,8955 x) kkal

Panas keluar :

Panas bahan = 1962382,9908 kkal

Panas flue gas = 6721,2493 x kkal

Panas yang hilang = 2773,9824 x kkal

= (1962382,9908 + 9495,2317 x) kkal

Panas masuk = panas keluar

548547,4660 + 13894,8955 x = 1962382,9908 + 9495,2317 x

x = 321,3508 kg / jam

Panas bahan bakar = 3,9756 x = 3,9756 * 321,3508 = 1277,5623 kkal

Panas pembakaran = 13869,9122 x = 13869,9122 * 321,3508

= 4457107,381 kkal

Panas udara = 21,0077 x = 21,0077 * 321,3508 = 6750,8412 kkal

Panas flue gas = 6721,2493 x = 6721,2493 * 321,3508

= 2159878,84 kkal

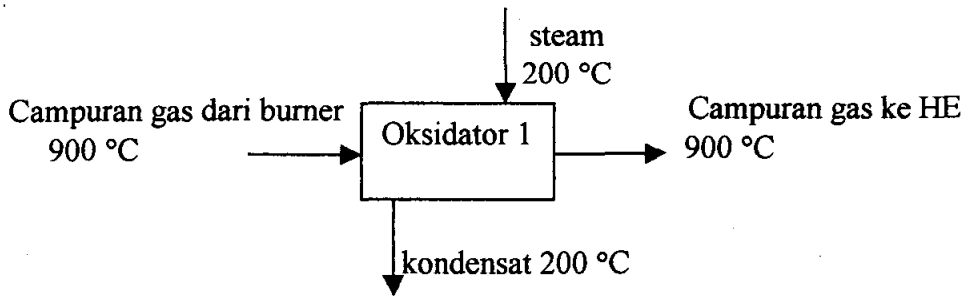
Panas yang hilang = 2773,9824 x = 2773,9824 * 321,3508

= 891421,4634 kkal

Neraca panas :

Masuk	Kkal / jam	Keluar	kkal / jam
Panas bahan	548547,4660	Panas bahan	1962382,9908
Panas udara	6750,8412	Panas flue gas	2159878,8400
Panas pembakaran	4457107,3810	Panas yang hilang	891421,4634
Panas bahan bakar	1277,5623		
Total	5013683,2510		5013683,2510

2. Oksidator 1 (R – 210)



Reaksi : $NH_3 + \frac{5}{4} O_2 \longrightarrow NO + \frac{3}{2} H_2O \quad \Delta H_1 = -54{,}3062$ kkal / mol

$NH_3 + \frac{3}{2} O_2 \longrightarrow \frac{1}{2} N_2 + \frac{3}{2} H_2O \quad \Delta H_2 = -75{,}8373$ kkal / mol

NH_3 yang bereaksi pada reaksi 1 = 24,1044 kmol = 24104,4 mol

ΔH_{r1} = 24104,4 * (-54,3062) = -1309018,311 kkal / jam

NH_3 yang bereaksi pada reaksi 2 = 1,0043 kmol = 1004,3 mol

ΔH_{r1} = 1004,3 * (-75,8373) = -76167,1890 kkal / jam

Panas reaksi eksotermis $= \Delta H_{r1} + \Delta H_{r2}$

$= -1309018{,}311 + (-76167{,}1890)$

$= -1385185{,}5000$ kkal / jam

<u>Panas masuk :</u>

Suhu gas masuk = 900 °C

$T = \frac{900 + 25}{2} = 462{,}5$ °C = 864,5 °F

Dari Kern fig. 3 :

Cp NH_3 = 0,66 Btu / lb °F = 0,66 kkal / kg °C

Cp H_2O = 0,49 Btu / lb °F = 0,49 kkal / kg °C

Cp N_2 = 0,26 Btu / lb °F = 0,25 kkal / kg °C

Cp O_2 = 0,245 Btu / lb °F = 0,265 kkal / kg °C

H_{igNH3} = m * Cp * ΔT = 426,8487 * 0,66 * (900 - 25) = 246505,1424 kkal

H_{igH2O} = m * Cp * ΔT = 134,2672 * 0,49 * (900 - 25) = 57567,0809 kkal

H_{igN2} = m * Cp * ΔT = 5790,6573 * 0,26 * (900 - 25) = 1317374,5350 kkal

H_{igO2} = m * Cp * ΔT = 1759,1870 * 0,245 * (900 - 25) = 377125,7189 kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K

Pc N2 = 34 atm

ω N2 = 0,0,038

Tc O2 = 154,6 K

Pc O2 = 50,43 atm

ω O2 = 0,022

$$Tr\ N2 = \frac{900+273}{126,2} = 9,2948$$

$$Pr\ N2 = \frac{9.86}{34} = 0,29$$

$$Tr\ O2 = \frac{900+273}{154,6} = 7,5873$$

$$Pr\ O2 = \frac{9.86}{50,43} = 0,1955$$

Tc H2O = 647,1 K

Pc H2O = 220,5 atm

ω H2O = 0,345

Tc NH3 = 405,7 K

Pc NH3 = 112,8 atm

ω NH3 = 0,253

$$Tr\ H2O = \frac{900+273}{647,1} = 1,8127$$

$$Pr\ H2O = \frac{9,86}{220,5} = 0,0447$$

$$Tr\ NH3 = \frac{900+273}{154,6} = 2,8913$$

$$Pr\ NH3 = \frac{9.86}{50,43} = 0,195$$

Dari Smith Van Ness app B:

$\frac{(H^R)^0}{RT_c}_{N2} = 0,0039$ $\frac{(H^R)^0}{RT_c}_{H2O} = -0,0149$

$\frac{(H^R)^1}{RT_c}_{N2} = 0,0419$ $\frac{(H^R)^1}{RT_c}_{H2O} = 0,0011$

$\frac{(H^R)^0}{RT_c}_{O2} = -0,0007$ $\frac{(H^R)^0}{RT_c}_{NH3} = -0,0066$

$\frac{(H^R)^1}{RT_c}_{O2} = 0,0385$ $\frac{(H^R)^1}{RT_c}_{NH3} = 0,0122$

$$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right) . R . T_c$$

$(H^R)_{N2}$ = ((0,0039 + (0,038. 0,0419)). 8,314 . 126,2) / 4,2

= 1,3720 kkal/kmol

= 1,3720 kkal/kmol x 206,6092 kmol = 283,7503 kkal

$(H^R)_{O2}$ = ((-0,0007 + (0,022. 0,0385)). 8,314 . 154,6) / 4,2

= 0,045 kkal/kmol

= 0,045 kkal/kmol x 54,9746 kmol = 2,4731 kkal

$(H^R)_{H2O}$ = ((-0,0149 + (0,345. 0,0011)). 8,314 . 647,1) / 4,2

= -18,60 kkal/kmol

= -18,60 kkal/kmol x 7,3401 kmol = -138,7431 kkal

$(H^R)_{NH3}$ = ((-0,0066 + (0,253. 0,0122)). 8,314 . 647,1) / 4,2

= -4,4278 kkal/kmol

= -4,4278 kkal/kmol x 25,1087 kmol = -111,1758 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2}$ = 1317374,5351 + 283,7503 = 1317658,2854 kkal

$H_{O2} = H_{igO2} + (H^R)_{O2}$ = 361732,8324 + 2,4731 = 361735,3056 kkal

$H_{H2O} = H_{igH2O} + (H^R)_{H2O}$ = 55217,4042 + -138,7431 = 55078,6611 kkal

$H_{NH3} = H_{igNH3} + (H^R)_{NH3}$ = 220360,6576 + -111,1758 = 220249,4818 kkal

Total panas masuk =1962382,9908 kkal

Panas keluar :

Suhu gas keluar = 900 °C

$$T = \frac{900 + 25}{2} = 462{,}5\ ^\circ C = 864{,}5\ ^\circ F$$

Dari kern fig. 3 :

Cp NO = 0,255 Btu / lb °F = 0,255 kkal / kg °C

Cp H_2O = 0,51 Btu / lb °F = 0,49 kkal / kg °C

Cp N_2 = 0,265 Btu / lb °F = 0,25 kkal / kg °C

Cp O_2 = 0,25 Btu / lb °F = 0,265 kkal / kg °C

H_{igNO} = m * Cp * ΔT = 723,1320 * 0,255 * (900 - 25) = 161348,8205 kkal

H_{igH2O} = m * Cp * ΔT = 812,2035 * 0,51 * (900 - 25) = 362445,7962 kkal

H_{igN2} = m * Cp * ΔT = 5804,7182 * 0,265 * (900 - 25) = 1345969,0319 kkal

H_{O2} = m * Cp * ΔT = 770,9067 * 0,25 * (900 - 25) = 168635,8340 kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K	Tc H2O = 647,1 K
Pc N2 = 34 atm	Pc H2O = 220,5 atm
ω N2 = 0,0,038	ω H2O = 0,345

Tc O2 = 154,6 K

Pc O2 = 50,43 atm

ω O2 = 0,022

Tc NO = 180,2 K

Pc NO = 64,8 atm

ω NO = 0,583

Tc NH3 = 405,7 K

Pc NH3 = 112,8 atm

ω NH3 = 0,253

$$\text{Tr N2} = \frac{900+273}{126,2} = 9,2948$$

$$\text{Pr N2} = \frac{9.37}{34} = 0,29$$

$$\text{Tr O2} = \frac{900+273}{154,6} = 7,5873$$

$$\text{Pr O2} = \frac{9.37}{50,43} = 0,1955$$

$$\text{Tr H2O} = \frac{900+273}{647,1} = 1,8127$$

$$\text{Pr H2O} = \frac{9,37}{220,5} = 0,0447$$

$$\text{Tr NO} = \frac{900+273}{180,2} = 6,5094$$

$$\text{Pr NO} = \frac{9.37}{64,8} = 0,1448$$

Dari Smith Van Ness app B:

$$\frac{(H^R)^0}{RT_c}_{N2} = 0,0039$$

$$\frac{(H^R)^1}{RT_c}_{N2} = 0,0419$$

$$\frac{(H^R)^0}{RT_c}_{O2} = -0,0007$$

$$\frac{(H^R)^1}{RT_c}_{O2} = 0,0385$$

$$\frac{(H^R)^0}{RT_c}_{H2O} = -0,0149$$

$$\frac{(H^R)^1}{RT_c}_{H2O} = 0,0011$$

$$\frac{(H^R)^0}{RT_c}_{NO} = 0,0123$$

$$\frac{(H^R)^1}{RT_c}_{NO} = 0,0251$$

$$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right) . R . T_c$$

$(H^R)_{N2}$ = ((0,0039 + (0,038. 0,0419)). 8,314 . 126,2) / 4,2

= 1,3720 kkal/kmol

= 1,3720 kkal/kmol x 207,3114 kmol = 284,4393 kkal

$(H^R)_{O2}$ = ((-0,0007 + (0,022. 0,0385)). 8,314 . 154,6) / 4,2

= 0,045 kkal/kmol

= 0,045 kkal/kmol x 24,0908 kmol = 1,0838 kkal

$(H^R)_{H2O}$ = ((-0,0149 + (0,345. 0,0011)). 8,314 . 647,1) / 4,2

= -18,60 kkal/kmol

= -18,60 kkal/kmol x 45,1224 kmol = -839,2784 kkal

$(H^R)_{NO}$ = ((0,0123 + (0,583. 0,0251)). 8,314 .180,2) / 4,2

= 9,6074 kkal/kmol

= 9,6074 kkal/kmol x 24,1044 kmol = 231,5802 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2}$ = 1345969,0319 + 284,4393 = 1325319,5423 kkal

$H_{O2} = H_{igO2} + (H^R)_{O2}$ = 168635,8340 + 1,0838 = 168636,9178 kkal

$H_{H2O} = H_{igH2O} + (H^R)_{H2O}$ = 362445,7962 + -839,2784 = 361606,5178 kkal

$H_{NO} = H_{igNO} + (H^R)_{NO}$ = 161348,8205 + 231,5802 = 161580,4007 kkal

Total panas keluar = 2038077,3074 kkal

Panas masuk = panas keluar + panas reaksi + Q

1962382,9908 = 2038077,3074 – 1385185,5 + Q

Q = 1309491,1830 kkal / jam = 5456213,2630 kj/kg

Kebutuhan steam :

Suhu steam masuk = 200°C

Dari Geankoplis, app.A. :

λ steam = 1940,75 kj/kg

$Q = m * \lambda$

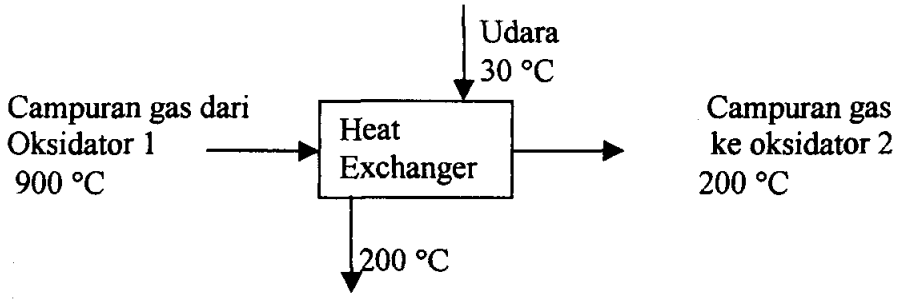
$m = \frac{Q}{\lambda}$

$= \frac{5456213,2630}{1940,75} = 2811,3942$ kg

Neraca panas :

Masuk	kkal / jam	Keluar	kkal /jam
Panas masuk	1962382,9908	Panas keluar	2038077,3074
Panas reaksi	1385185,5000	Panas diserap	1309491,1830
Total	3347568,4900	Total	3347568,4900

3. Heat Exchanger (E – 212)



Suhu gas masuk = 900 °C

$T = \frac{900 + 25}{2} = 462,5$ °C = 864,5 °F

Dari Kern fig. 3 :

Cp NO = 0,255 Btu / lb °F = 0,255 kkal / kg °C

Cp H_2O = 0,51 Btu / lb °F = 0,51 kkal / kg °C

Cp N_2 = 0,265 Btu / lb °F = 0,265 kkal / kg °C

Cp O_2 = 0,25 Btu / lb °F = 0,25 kkal / kg °C

H_{igNO} = m * Cp * ΔT = 723,1320 * 0,255 * (900 - 25) = 161348,8205 kkal

H_{igH2O} = m * Cp * ΔT = 812,2035 * 0,51 * (900 - 25) = 362445,7962 kkal

H_{igN2} = m * Cp * ΔT = 5804,7182 * 0,265 * (900 - 25) = 1345969,0319 kkal

H_{O2} = m * Cp * ΔT = 770,9067 * 0,25 * (900 - 25) = 168635,8340 kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K

Pc N2 = 34 atm

ω N2 = 0,0,038

Tc O2 = 154,6 K

Pc O2 = 50,43 atm

ω O2 = 0,022

Tc H2O = 647,1 K

Pc H2O = 220,5 atm

ω H2O = 0,345

Tc NO = 180,2 K

Pc NO = 64,8 atm

ω NO = 0,583

$$\text{Tr N2} = \frac{900+273}{126,2} = 9,2948$$

$$\text{Tr H2O} = \frac{900+273}{647,1} = 1,8127$$

$$\text{Pr N2} = \frac{9.37}{34} = 0,29$$

$$\text{Pr H2O} = \frac{9,37}{220,5} = 0,0447$$

$$\text{Tr O2} = \frac{900+273}{154,6} = 7,5873$$

$$\text{Tr NO} = \frac{900+273}{180,2} = 6,5094$$

$$\text{Pr O2} = \frac{9.37}{50,43} = 0,1955$$

$$\text{Pr NO} = \frac{9.37}{64,8} = 0,1448$$

Dari Smith Van Ness app B:

$\frac{(H^R)^0}{RT_c}_{N2} = 0,0039$ $\frac{(H^R)^0}{RT_c}_{H2O} = -0,0149$

$\frac{(H^R)^1}{RT_c}_{N2} = 0,0419$ $\frac{(H^R)^1}{RT_c}_{H2O} = 0,0011$

$\frac{(H^R)^0}{RT_c}_{O2} = -0,0007$ $\frac{(H^R)^0}{RT_c}_{NO} = 0,0123$

$\frac{(H^R)^1}{RT_c}_{O2} = 0,0385$ $\frac{(H^R)^1}{RT_c}_{NO} = 0,0251$

$$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right) . R . T_c$$

$(H^R)_{N2}$ = ((0,0039 + (0,038. 0,0419)). 8,314 . 126,2) / 4,2

= 1,3720 kkal/kmol

= 1,3720 kkal/kmol x 207,3114 kmol = 284,4393 kkal

$(H^R)_{O2}$ = ((-0,0007 + (0,022. 0,0385)). 8,314 . 154,6) / 4,2

= 0,045 kkal/kmol

= 0,045 kkal/kmol x 24,0908 kmol = 1,0838 kkal

$(H^R)_{H2O}$ = ((-0,0149 + (0,345. 0,0011)). 8,314 . 647,1) / 4,2

= -18,60 kkal/kmol

= -18,60 kkal/kmol x 45,1224 kmol = -839,2784 kkal

$(H^R)_{NO}$ = ((0,0123 + (0,583. 0,0251)). 8,314 .180,2) / 4,2

= 9,6074 kkal/kmol

= 9,6074 kkal/kmol x 24,1044 kmol = 231,5802 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2}$ = 1345969,0319 + 284,4393 = 1325319,5423 kkal

$H_{O2} = H_{igO2} + (H^R)_{O2}$ = 168635,8340 + 1,0838 = 168636,9178 kkal

$H_{H2O} = H_{igH2O} + (H^R)_{H2O}$ = 362445,7962 + -839,2784 = 361606,5178 kkal

$H_{NO} = H_{igNO} + (H^R)_{NO}$ = 161348,8205 + 231,5802 = 161580,4007 kkal

Total panas masuk = 2038077,3074 kkal

Panas Keluar :

Suhu gas keluar = 200 °C

$$T = \frac{200 + 25}{2} = 112{,}5\ ^\circ C = 234{,}5\ ^\circ F$$

Dari Kern fig. 3 :

Cp NO = 0,235 Btu / lb °F = 0,235 kkal / kg °C

Cp H_2O = 0,455 Btu / lb °F = 0,455 kkal / kg °C

Cp N_2 = 0,255 Btu / lb °F = 0,255 kkal / kg °C

Cp O_2 = 0,225 Btu / lb °F = 0,225 kkal / kg °C

H_{igNO} = m * Cp * ΔT = 723,1320 * 0,235 * (200 - 25) = 29738,8022 kkal

H_{igH2O} = m * Cp * ΔT = 812,2035 * 0,455 * (200 - 25) = 64671,7009 kkal

H_{igN2} = m * Cp * ΔT = 5804,7182 * 0,255 * (200 - 25) = 259035,5495 kkal

H_{igO2} = m * Cp * ΔT = 770,9067 * 0,225 * (200 - 25) = 30354,4501 kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K	Tc H2O = 647,1 K
Pc N2 = 34 atm	Pc H2O = 220,5 atm
ω N2 = 0,0,038	ω H2O = 0,345
Tc O2 = 154,6 K	Tc NO = 180,2 K

Pc O2 = 50,43 atm

Pc NO = 64,8 atm

ω O2 = 0,022

ω NO = 0,583

$Tr\ N2 = \frac{200+273}{126,2} = 3,1632$

$Tr\ H2O = \frac{200+273}{647,1} = ,7310$

$Pr\ N2 = \frac{9.37}{34} = 0,29$

$Pr\ H2O = \frac{9,37}{220,5} = 0,0447$

$Tr\ O2 = \frac{200+273}{154,6} = 3,0595$

$Tr\ NO = \frac{200+273}{180,2} = 2,6249$

$Pr\ O2 = \frac{9.37}{50,43} = 0,1955$

$Pr\ NO = \frac{9.37}{64,8} = 0,1448$

Dari Smith Van Ness app B:

$\frac{(H^R)^0}{RT_c}_{N2} = -0.0162$

$\frac{(H^R)^0}{RT_c}_{H2O} = -0,0789$

$\frac{(H^R)^1}{RT_c}_{N2} = 0,0434$

$\frac{(H^R)^1}{RT_c}_{H2O} = -0,1343$

$\frac{(H^R)^0}{RT_c}_{O2} = -0.0204$

$\frac{(H^R)^0}{RT_c}_{NO} = -0,0227$

$\frac{(H^R)^1}{RT_c}_{O2} = 0,0271$

$\frac{(H^R)^1}{RT_c}_{NO} = 0,0092$

$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right) . R . T_c$

$(H^R)_{N2}$ = ((-0,0162 + (0,038. 0,0434)). 8,314 . 126,2) / 4,2

= -3,6350 kkal/kmol

= -3,6350 kkal/kmol x 207,3114 kmol = -753,5812 kkal

$(H^R)_{O2}$ = ((-0,0204 + (0,022. 0,0271)). 8,314 . 154,6) / 4,2

= -6,0606 kkal/kmol

= -6,0606 kkal/kmol x 24,0908 kmol = -146,0060 kkal

$(H^R)_{H2O}$ = ((-0,0789 + 0,345. (-0,1343)). 8,314 . 647,1) / 4,2

= -160,4178 kkal/kmol

= -160,4178 kkal/kmol x 45,1224 kmol = -7238,4400 kkal

$(H^R)_{NO}$ = ((-0,0227 + (0,583. 0,0092)). 8,314 .180,2) / 4,2

= -6,1841 kkal/kmol

= -6,1841 kkal/kmol x 24,1044 kmol = -149,0633 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2}$ = 259035,5495 - 753,5812 = 258281,9683 kkal

$H_{O2} = H_{igO2} + (H^R)_{O2}$ = 30354,4501 – 146,0060 = 30208,4442 kkal

$H_{H2O} = H_{igH2O} + (H^R)_{H2O}$ = 64671,7009 – 7238,4400 = 57433,2609 kkal

$H_{NO} = H_{igNO} + (H^R)_{NO}$ = 29738,8022 – 149,0633 = 29589,7389 kkal

Total panas keluar = 375513,4122 kkal

Panas yang hilang = 5 % dari panas masuk

= 0,05 * 2038077,3074

= 101903,8654 kkal / jam

Panas masuk = panas keluar + panas hilang + Q

2038077,3074 = 375513,4122 + 101903,8654 + Q

Q = 1560660,0298 kkal / jam

Kebutuhan udara :

$$T = \frac{30 + 200}{2} = 115\ ^\circ C = 239\ ^\circ F$$

Dari Kern fig. 3 :

Cp udara = 0,25 Bbtu / lb °F = 0,25 kkal / kg °C

$Q = m * Cp * \Delta T$

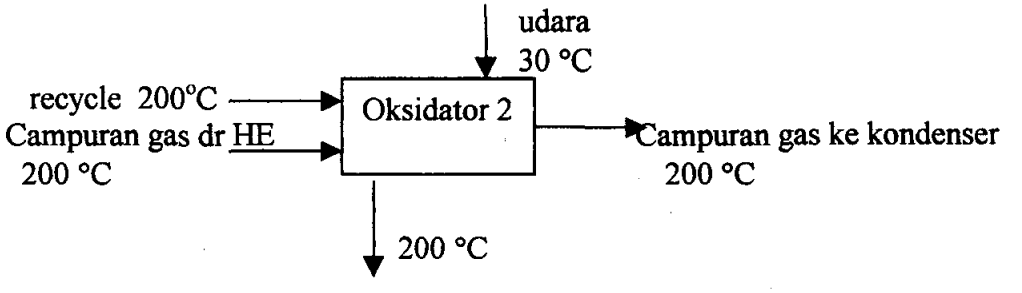
$$m = \frac{Q}{Cp * \Delta T}$$

$$= \frac{1560660,0298}{0,25 * (200 - 30)} = 36721,4125 \text{ kg / jam}$$

Neraca Panas :

Masuk	kkal / jam	Keluar	kkal / jam
Panas masuk	2038077,3074	Panas keluar	375513,4122
		Panas hilang	101903,8654
		Panas diserap	1560660,0298
Total	2038077,3074		2038077,3074

4. Oksidator 2 (R – 230)



Reaksi : $NO + \frac{1}{2} O_2 \longrightarrow NO_2$ ΔH = -27,3 kkal / mol

NO yang bereaksi = 27,9151 kmol = 27915,1 mol

ΔH_r = -27,3 * 27915,1 = -762081,5341 kkal / jam

Panas masuk :

Suhu gas masuk = 200 °C

$$T = \frac{200 + 25}{2} = 112{,}5\ ^\circ C = 385{,}5\ ^\circ K = 234{,}5\ ^\circ F$$

Dari bahan :

Dari Kern fig. 3 :

Cp NO = 0,235 Btu / lb °F = 0,235 kkal / kg °C

Cp H_2O = 0,455 Btu / lb °F = 0,455 kkal / kg °C

Cp N_2 = 0,255 Btu / lb °F = 0,255 kkal / kg °C

Cp O_2 = 0,225 Btu / lb °F = 0,225 kkal / kg °C

Massa total NO masuk = 881,5287 kg/jam = 29,3843 kmol/jam

Massa total N2 masuk = 11609,4364 kg/jam = 414,6227 kmol/jam

Massa total O2 masuk = 1095,7442 kg/jam = 34,2420 kmol/jam

Massa total H2O masuk = 812,2035 kg/jam = 45,1224 kmol/jam

Massa total NO2 masuk = 32,8833 kg/jam = 0,8221 kmol/jam

H_{igNO} = m * Cp * ΔT = 881,5287 * 0,235 * (200 - 25) = 36252,8665 kkal

H_{igNO2} = m * Cp * ΔT = 32,8833 * 0,011 * (200 - 25) = 63,3004 kkal

H_{igH2O} = m * Cp * ΔT = 812,2035 * 0,455 * (200 - 25) = 64671,7009 kkal

H_{igN2} = m * Cp * ΔT = 11609,4364 * 0,255 * (200 - 25) = 518071,0992 kkal

H_{igO2} = m * Cp * ΔT = 1095,7442 * 0,225 * (200 - 25) = 43144,9267 kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K Tc H2O = 647,1 K

Pc N2 = 34 atm Pc H2O = 220,5 atm

ω N2 = 0,0,038

Tc O2 = 154,6 K

Pc O2 = 50,43 atm

ω O2 = 0,022

Tc NO2 = 309,6 K

Pc NO2 = 72,45 atm

ω NO2 = 0,141

ω H2O = 0,345

Tc NO = 180,2 K

Pc NO = 64,8 atm

ω NO = 0,583

$$\text{Tr N2} = \frac{200+273}{126,2} = 3,1632$$

$$\text{Tr H2O} = \frac{200+273}{647,1} = ,7310$$

$$\text{Pr N2} = \frac{9.37}{34} = 0,29$$

$$\text{Pr H2O} = \frac{9,37}{220,5} = 0,0447$$

$$\text{Tr O2} = \frac{200+273}{154,6} = 3,0595$$

$$\text{Tr NO} = \frac{200+273}{180,2} = 2,6249$$

$$\text{Pr O2} = \frac{9.37}{50,43} = 0,1955$$

$$\text{Pr NO} = \frac{9.37}{64,8} = 0,1448$$

$$\text{Tr NO2} = \frac{200+273}{309,6} = 1,5278$$

$$\text{Pr NO2} = \frac{9.37}{72,45} = 1,2473$$

Dari Smith Van Ness app B:

$$\left(\frac{(H^R)^0}{RT_c}\right)_{N2} = -0.0162$$

$$\left(\frac{(H^R)^0}{RT_c}\right)_{H2O} = -0,0789$$

$$\left(\frac{(H^R)^1}{RT_c}\right)_{N2} = 0,0434$$

$$\left(\frac{(H^R)^1}{RT_c}\right)_{H2O} = -0,1343$$

$$\left(\frac{(H^R)^0}{RT_c}\right)_{O2} = -0.0204$$

$$\left(\frac{(H^R)^0}{RT_c}\right)_{NO} = -0,0227$$

$\frac{(H^R)^1}{RT_c}_{O2} = 0{,}0271$ $\frac{(H^R)^1}{RT_c}_{NO} = 0{,}0092$

$\frac{(H^R)^0}{RT_c}_{NO2} = -0{,}0605$

$\frac{(H^R)^1}{RT_c}_{NO2} = -0{,}0097$

$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right)$. R. T_c

$(H^R)_{N2}$ = ((-0,0162 + (0,038. 0,0434)). 8,314 . 126,2) / 4,2

= -3,6350 kkal/kmol

= -3,6350 kkal/kmol x 414,6227 kmol = -1507,1624 kkal

$(H^R)_{O2}$ = ((-0,0204 + (0,022. 0,0271)). 8,314 . 154,6) / 4,2

= -6,0606 kkal/kmol

= -6,0606 kkal/kmol x 34,2420 kmol = -207,5286 kkal

$(H^R)_{H2O}$ = ((-0,0789 + 0,345. (-0,1343)). 8,314 . 647,1) / 4,2

= -160,4178 kkal/kmol

= -160,4178 kkal/kmol x 45,1224 kmol = -7238,4400 kkal

$(H^R)_{NO}$ = ((-0,0227 + (0,583. 0,0092)). 8,314 .180,2) / 4,2

= -6,1841 kkal/kmol

= -6,1841 kkal/kmol x 29,3843 kmol = -181,7145 kkal

$(H^R)_{NO2}$ = ((-0,0605 + (0,141. -0,0097)). 8,314 .180,2) / 4,2

= -37,9163 kkal/kmol

= -37,9163 kkal/kmol x 0,8221 kmol = -31,1703 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2} = 518071,0992 - 1507,1624 = 516563,9368$ kkal

$H_{O2} = H_{igO2} + (H^R)_{O2} = 43144,9267 - 207,5286 = 42937,3981$ kkal

$H_{H2O} = H_{igH2O} + (H^R)_{H2O} = 64671,7009 - 7238,4400 = 57433,2609$ kkal

$H_{NO} = H_{igNO} + (H^R)_{NO} = 36252,8665 - 181,7145 = 36071,1520$ kkal

$H_{NO2} = H_{igNO2} + (H^R)_{NO2} = 63,3004 - 31,1703 = 32,1300$ kkal

Total panas masuk = 653037,8777 kkal

Panas keluar :

Suhu gas keluar pada suhu = 200 °C

$$T = \frac{200 + 25}{2} = 112,5 \text{ °C} = 234,5 \text{ °F}$$

Dari Kern fig. 3 :

Cp NO = 0,235 Btu / lb °F = 0,235 kkal / kg °C

Cp H_2O = 0,455 Btu / lb °F = 0,455 kkal / kg °C

Cp NO_2 = 0,011 Btu / lb °F = 0,011 kkal / kg °C

Cp N_2 = 0,255 Btu / lb °F = 0,255 kkal / kg °C

Cp O_2 = 0,225 Btu / lb °F = 0,225 kkal / kg °C

$H_{igNO} = m * Cp * \Delta T = 44,0764 * 0,235 * (200 - 25) = 1812,6433$ kkal

$H_{igNO2} = m * Cp * \Delta T = 1316,9767 * 0,011 * (200 - 25) = 2535,1802$ kkal

$H_{igH2O} = m * Cp * \Delta T = 812,2035 * 0,455 * (200 - 25) = 64671,7009$ kkal

$H_{igN2} = m * Cp * \Delta T = 11609,4364 * 0,255 * (200 - 25) = 518071,0992$ kkal

$H_{igO2} = m * Cp * \Delta T = 649,1030 * 0,225 * (200 - 25) = 25558,4298$ kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K

Pc N2 = 34 atm

ω N2 = 0,0,038

Tc O2 = 154,6 K

Pc O2 = 50,43 atm

ω O2 = 0,022

Tc NO2 = 309,6 K

Pc NO2 = 72,45 atm

ω NO2 = 0,141

Tc H2O = 647,1 K

Pc H2O = 220,5 atm

ω H2O = 0,345

Tc NO = 180,2 K

Pc NO = 64,8 atm

ω NO = 0,583

$$\text{Tr N2} = \frac{200+273}{126,2} = 3,1632$$

$$\text{Pr N2} = \frac{9.37}{34} = 0,29$$

$$\text{Tr O2} = \frac{200+273}{154,6} = 3,0595$$

$$\text{Pr O2} = \frac{9.37}{50,43} = 0,1955$$

$$\text{Tr NO2} = \frac{200+273}{309,6} = 1,5278$$

$$\text{Pr NO2} = \frac{9.37}{72,45} = 1,2473$$

$$\text{Tr H2O} = \frac{200+273}{647,1} = ,7310$$

$$\text{Pr H2O} = \frac{9,37}{220,5} = 0,0447$$

$$\text{Tr NO} = \frac{200+273}{180,2} = 2,6249$$

$$\text{Pr NO} = \frac{9.37}{64,8} = 0,1448$$

Dari Smith Van Ness app B:

$$\frac{(H^R)^0}{RT_c}_{\text{N2}} = -0.0162$$

$$\frac{(H^R)^0}{RT_c}_{\text{H2O}} = -0,0789$$

$\frac{(H^R)^1}{RT_c}_{N2} = 0{,}0434$ $\frac{(H^R)^1}{RT_c}_{H2O} = -0{,}1343$

$\frac{(H^R)^0}{RT_c}_{O2} = -0.0204$ $\frac{(H^R)^0}{RT_c}_{NO} = -0{,}0227$

$\frac{(H^R)^1}{RT_c}_{O2} = 0{,}0271$ $\frac{(H^R)^1}{RT_c}_{NO} = 0{,}0092$

$\frac{(H^R)^0}{RT_c}_{NO2} = -0{,}0605$

$\frac{(H^R)^1}{RT_c}_{NO} = -0{,}0097$

$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right) . R . T_c$

$(H^R)_{N2} = ((-0{,}0162 + (0{,}038 . 0{,}0434)) . 8{,}314 . 126{,}2) / 4{,}2$

$= -3{,}6350$ kkal/kmol

$= -3{,}6350$ kkal/kmol x 414,6227 kmol = -1507,1624 kkal

$(H^R)_{O2} = ((-0{,}0204 + (0{,}022 . 0{,}0271)) . 8{,}314 . 154{,}6) / 4{,}2$

$= -6{,}0606$ kkal/kmol

$= -6{,}0606$ kkal/kmol x 28,6299 kmol = -122,9369 kkal

$(H^R)_{H2O} = ((-0{,}0789 + 0{,}345 . (-0{,}1343)) . 8{,}314 . 647{,}1) / 4{,}2$

$= -160{,}4178$ kkal/kmol

$= -160{,}4178$ kkal/kmol x 45,1224 kmol = -7238,4400 kkal

$(H^R)_{NO} = ((-0{,}0227 + (0{,}583 . 0{,}0092)) . 8{,}314 . 180{,}2) / 4{,}2$

$= -6{,}1841$ kkal/kmol

$= -6{,}1841$ kkal/kmol x 1,4692 kmol = -9,0857 kkal

$(H^R)_{NO2}$ = ((-0,0605 + (0,141. -0,0097)). 8,314 .180,2) / 4,2

= -37,9163 kkal/kmol

= -37,9163 kkal/kmol x 28,6299 kmol = -1085,5402 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2}$ = 518071,0992 – 1507,1624 = 516563,9368 kkal

$H_{O2} = H_{igO2} + (H^R)_{O2}$ = 25558,4298 – 122,9369 = 25435,4928 kkal

$H_{H2O} = H_{igH2O} + (H^R)_{H2O}$ = 64671,7009 – 7238,4400 = 57433,2609 kkal

$H_{NO} = H_{igNO} + (H^R)_{NO}$ = 1812,6433 – 9,0857 = 1803,5576 kkal

$H_{NO2} = H_{igNO2} + (H^R)_{NO2}$ = 2535,1802 – 1085,5402 = 1449,6400 kkal

Total panas keluar = 602685,8880 kkal

Panas masuk = panas keluar + panas reaksi + Q

653037,8777 = 602685,8880 – 762081,5341 + Q

Q = 812433,5238 kkal / jam

Kebutuhan udara sebagai pendingin :

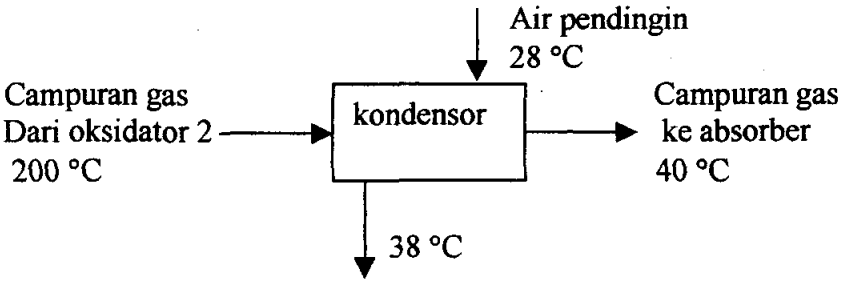
$$m = \frac{Q}{Cp * \Delta T}$$

$$m = \frac{812433,5238}{0,25 * (200 - 30)} = 19116,0829 \text{ kg / jam}$$

Neraca panas :

Masuk	kkal / jam	Keluar	kkal / jam
Panas masuk	653037,8777	Panas keluar	602685,8880
Panas reaksi	762081,5341	Panas diserap	812433,5238
Total	1415119,4118		1415119,4118

5. Kondenser (E –231)



Dari Geankoplis tab. A.2-9 :

Panas laten kondensasi (λ) = 2406,73 kj / kg

= 575,22 kkal / kg

H_2O yang mengembun = 727,2250 kg / jam

Panas kondensasi = 727,2250 * 575,22 = 418314,3549 kkal

Suhu gas masuk pada suhu = 200 °C

$$T = \frac{210 + 25}{2} = 117{,}5 \text{ °C} = 243{,}5 \text{ °F}$$

Dari Kern fig. 3 :

Cp NO = 0,235 Btu / lb °F = 0,235 kkal / kg °C

Cp H_2O = 0,455 Btu / lb °F = 0,455 kkal / kg °C

Cp NO_2 = 0,011 kkal / mol °K

Cp N_2 = 0,255 Btu / lb °F = 0,255 kkal / kg °C

Cp O_2 = 0,225 Btu / lb °F = 0,225 kkal / kg °C

H_{igNO} = m * Cp * ΔT = 44,0764 * 0,235 * (200 - 25) = 1812,6433 kkal

H_{igNO2} = m * Cp * ΔT = 1316,9767 * 0,011 * (200 - 25) = 2535,1802 kkal

H_{igH2O} = m * Cp * ΔT = 812,2035 * 0,455 * (200 - 25) = 64671,7009 kkal

H_{igN2} = m * Cp * ΔT = 11609,4364 * 0,255 * (200 - 25) = 518071,0992 kkal

H_{igO2} = m * Cp * ΔT = 649,1030 * 0,225 * (200 - 25) = 25558,4298 kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K

Pc N2 = 34 atm

ω N2 = 0,0,038

Tc O2 = 154,6 K

Pc O2 = 50,43 atm

ω O2 = 0,022

Tc NO2 = 309,6 K

Pc NO2 = 72,45 atm

ω NO2 = 0,141

Tc H2O = 647,1 K

Pc H2O = 220,5 atm

ω H2O = 0,345

Tc NO = 180,2 K

Pc NO = 64,8 atm

ω NO = 0,583

$Tr\ N2 = \frac{200+273}{126,2} = 3,1632$

$Pr\ N2 = \frac{9.37}{34} = 0,29$

$Tr\ O2 = \frac{200+273}{154,6} = 3,0595$

$Pr\ O2 = \frac{9.37}{50,43} = 0,1955$

$Tr\ NO2 = \frac{200+273}{309,6} = 1,5278$

$Pr\ NO2 = \frac{9.37}{72,45} = 1,2473$

$Tr\ H2O = \frac{200+273}{647,1} = ,7310$

$Pr\ H2O = \frac{9,37}{220,5} = 0,0447$

$Tr\ NO = \frac{200+273}{180,2} = 2,6249$

$Pr\ NO = \frac{9.37}{64,8} = 0,1448$

Dari Smith Van Ness app B:

$\frac{(H^R)^0}{RT_c}_{N2} = -0.0162$ $\frac{(H^R)^0}{RT_c}_{H2O} = -0,0789$

$\frac{(H^R)^1}{RT_c}_{N2} = 0,0434$ $\frac{(H^R)^1}{RT_c}_{H2O} = -0,1343$

$\frac{(H^R)^0}{RT_c}_{O2} = -0.0204$ $\frac{(H^R)^0}{RT_c}_{NO} = -0,0227$

$\frac{(H^R)^1}{RT_c}_{O2} = 0,0271$ $\frac{(H^R)^1}{RT_c}_{NO} = 0,0092$

$\frac{(H^R)^0}{RT_c}_{NO2} = -0,0605$

$\frac{(H^R)^1}{RT_c}_{NO} = -0,0097$

$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right) . R . T_c$

$(H^R)_{N2} = ((-0,0162 + (0,038 . 0,0434)) . 8,314 . 126,2) / 4,2$

$= -3,6350$ kkal/kmol

$= -3,6350$ kkal/kmol x 414,6227 kmol = -1507,1624 kkal

$(H^R)_{O2} = ((-0,0204 + (0,022 . 0,0271)) . 8,314 . 154,6) / 4,2$

$= -6,0606$ kkal/kmol

$= -6,0606$ kkal/kmol x 28,6299 kmol = -122,9369 kkal

$(H^R)_{H2O} = ((-0,0789 + 0,345 . (-0,1343)) . 8,314 . 647,1) / 4,2$

$= -160,4178$ kkal/kmol

$= -160,4178$ kkal/kmol x 45,1224 kmol = -7238,4400 kkal

$(H^R)_{NO}$ = ((-0,0227 + (0,583. 0,0092)). 8,314 .180,2) / 4,2

= -6,1841 kkal/kmol

= -6,1841 kkal/kmol x 1,4692 kmol = -9,0857 kkal

$(H^R)_{NO2}$ = ((-0,0605 + (0,141. -0,0097)). 8,314 .180,2) / 4,2

= -37,9163 kkal/kmol

= -37,9163 kkal/kmol x 28,6299 kmol = -1085,5402 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2}$ = 518071,0992 – 1507,1624 = 516563,9368 kkal

$H_{O2} = H_{igO2} + (H^R)_{O2}$ = 25558,4298 – 122,9369 = 25435,4928 kkal

$H_{H2O} = H_{igH2O} + (H^R)_{H2O}$ = 64671,7009 – 7238,4400 = 57433,2609 kkal

$H_{NO} = H_{igNO} + (H^R)_{NO}$ = 1812,6433 – 9,0857 = 1803,5576 kkal

$H_{NO2} = H_{igNO2} + (H^R)_{NO2}$ = 2535,1802 – 1085,5402 = 1449,6400 kkal

Total panas masuk = 602685,8880 kkal

Suhu gas keluar pada suhu = 40 °C

$$T = \frac{40 + 25}{2} = 32,5 \text{ °C} = 90,5 \text{ °F}$$

Dari Kern fig. 3 :

Cp NO = 0,23 Btu / lb °F = 0,23 kkal / kg °C

Cp H_2O = 0,45 Btu / lb °F = 0,45 kkal / kg °C

Cp NO_2 = $5,0901.10^{-3}$ kkal / mol °C

Cp N_2 = 0,25 Btu / lb °F = 0,25 kkal / kg °C

Cp O_2 = 0,22 Btu / lb °F = 0,22 kkal / kg °C

H_{igNO} = m * Cp * ΔT = 44,0764 * 0,235 * (40 - 25) = 1,4692 kkal

H_{igNO2} = m * Cp * ΔT = 1316,9767 * 0,0051 * (40 - 25) = 100,7000 kkal

H_{igH2O} = m * Cp * ΔT = 84,9785 * 0,45 * (40 - 25) = 573,6049 kkal

H_{igN2} = m * Cp * ΔT = 11609,4364 * 0,255 * (40 - 25) = 43535,3865 kkal

H_{igO2} = m * Cp * ΔT = 649,1030 * 0,225 * (40 - 25) = 2142,0398 kkal

H_{H2Oliq} = m * Cp * ΔT = 727,2250 * 1 * (40 - 25) = 10908,3750 kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K

Pc N2 = 34 atm

ω N2 = 0,0,038

Tc O2 = 154,6 K

Pc O2 = 50,43 atm

ω O2 = 0,022

Tc NO2 = 309,6 K

Pc NO2 = 72,45 atm

ω NO2 = 0,141

Tc H2O = 647,1 K

Pc H2O = 220,5 atm

ω H2O = 0,345

Tc NO = 180,2 K

Pc NO = 64,8 atm

ω NO = 0,583

$Tr\ N2 = \frac{40+273}{126,2} = 2,4802$

$Pr\ N2 = \frac{9.37}{34} = 0,29$

$Tr\ O2 = \frac{40+273}{154,6} = 2,0246$

$Pr\ O2 = \frac{9.37}{50,43} = 0,1955$

$Tr\ NO2 = \frac{40+273}{309,6} = 1,0110$

$Tr\ H2O = \frac{200+273}{647,1} = ,7310$

$Pr\ H2O = \frac{9,37}{220,5} = 0,0447$

$Tr\ NO = \frac{40+273}{180,2} = 1,7370$

$Pr\ NO = \frac{9.37}{64,8} = 0,1448$

$$\text{Pr NO2} = \frac{9.37}{72,45} = 1,2473$$

Dari Smith Van Ness app B:

$$\frac{(H^R)^0}{RT_c}_{N2} = -0.0491 \qquad \frac{(H^R)^0}{RT_c}_{H2O} = -0,5512$$

$$\frac{(H^R)^1}{RT_c}_{N2} = 0,0336 \qquad \frac{(H^R)^1}{RT_c}_{H2O} = -0,8869$$

$$\frac{(H^R)^0}{RT_c}_{O2} = -0.0427 \qquad \frac{(H^R)^0}{RT_c}_{NO} = -0,0528$$

$$\frac{(H^R)^1}{RT_c}_{O2} = 0,0139 \qquad \frac{(H^R)^1}{RT_c}_{NO} = 0,0019$$

$$\frac{(H^R)^0}{RT_c}_{NO2} = -0,1324$$

$$\frac{(H^R)^1}{RT_c}_{NO} = -0,1165$$

$$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right) . R . T_c$$

$(H^R)_{N2}$ = ((-0,0491 + (0,038. 0,0336)). 8,314 . 126,2) / 4,2

= -11,9470 kkal/kmol

= -11,9470 kkal/kmol x 414,6227 kmol = -4953,4961 kkal

$(H^R)_{O2}$ = ((-0,0427 + (0,022. 0,0139)). 8,314 . 154,6) / 4,2

= -12,9741 kkal/kmol

= -12,9741 kkal/kmol x 20,2845 kmol = -263,1724 kkal

$(H^R)_{H2O}$ = ((-0,5512 + 0,345. (-0,8869)). 8,314 . 647,1) / 4,2

= -1098,0052 kkal/kmol

= -1098,0052 kkal/kmol x 4,7210 kmol = -5183,7121 kkal

$(H^R)_{NO}$ = ((-0,0528 + (0,583. 0,0019)). 8,314 .180,2) / 4,2

= -18,4392 kkal/kmol

= -18,4392 kkal/kmol x 1,4692 kmol = -27,0911 kkal

$(H^R)_{NO2}$ = ((-0,1324 + (0,141. -0,1165)). 8,314 .180,2) / 4,2

= -91,2099 kkal/kmol

= -91,2099 kkal/kmol x 28,6299 kmol = -2611,3328 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2}$ = 43535,3865 – 4953,4961 = 516563,9368 kkal

$H_{O2} = H_{igO2} + (H^R)_{O2}$ = 2142,0398 – 263,1724 = 1878,8675 kkal

$H_{H2O} = H_{igH2O} + (H^R)_{H2O}$ = 573,6048 – 5183,7121 = -4610,1074 kkal

$H_{NO} = H_{igNO} + (H^R)_{NO}$ = 152,0637 – 27,0911 = 124,9726 kkal

$H_{NO2} = H_{igNO2} + (H^R)_{NO2}$ = 100,7487 – 2611,3328 = 1449,6400 kkal

H_{H2Oliq} = 10908,3750 kkal

Total panas keluar = 44373,4141 kkal

Panas masuk = panas keluar + panas pengembunan + Q

602685,8880 = 44373,4141 + 418314,3549 + Q

Q = 139998,1190 kkal

Kebutuhan air pendingin :

C_p air = 1 kkal / kg °C

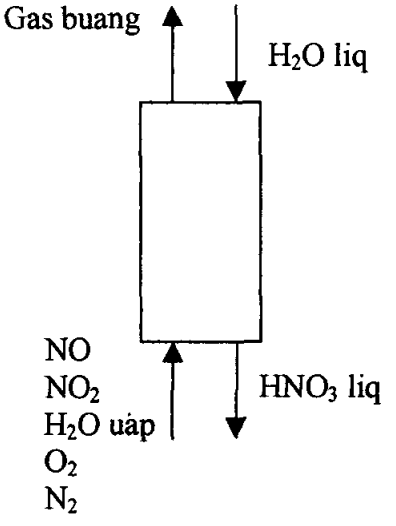
$$m = \frac{Q}{C_p * \Delta T} = \frac{139998,1190}{1*(38-28)}$$

m = 59171,1071 kg / jam

Neraca panas :

Masuk	kkal / jam	Keluar	kkal / jam
Panas total	602685,8880	Panas total	44373,4141
		Panas pengembunan	418314,3549
		Panas diserap	139998,1190
Total	602685,8880		602685,8880

6. Absorber (D – 240)



Reaksi : $3\ NO_2 + H_2O \longrightarrow 2\ HNO_3 + NO$ $\Delta H = -32,4$ kkal / mol

Panas reaksi :

$H_r = -32,4 * 1000 * 27,1984$

$H_r = -881229,2102$ kkal / jam

Panas masuk :

Suhu gas masuk pada suhu = 40 °C

$$T = \frac{40 + 25}{2} = 32{,}5\ ^{\circ}C = 90{,}5\ ^{\circ}F$$

Dari Kern fig. 3 :

Cp NO = 0,23 Btu / lb °F = 0,23 kkal / kg °C

Cp H_2O = 0,45 Btu / lb °F = 0,45 kkal / kg °C

Cp NO_2 = 0,0051 Btu / lb °F = 0,0051 kkal / kg °C

Cp N_2 = 0,25 Btu / lb °F = 0,25 kkal / kg °C

Cp O_2 = 0,22 Btu / lb °F = 0,22 kkal / kg °C

H_{igNO} = m * Cp * ΔT = 44,0764 * 0,235 * (40 - 25) = 1,4692 kkal

H_{igNO2} = m * Cp * ΔT = 1316,9767 * 0,0051 * (40 - 25) = 100,7000 kkal

H_{igH2O} = m * Cp * ΔT = 84,9785 * 0,45 * (40 - 25) = 573,6049 kkal

H_{igN2} = m * Cp * ΔT = 11609,4364 * 0,255 * (40 - 25) = 43535,3865 kkal

H_{igO2} = m * Cp * ΔT = 649,1030 * 0,225 * (40 - 25) = 2142,0398 kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K

Pc N2 = 34 atm

ω N2 = 0,0,038

Tc O2 = 154,6 K

Pc O2 = 50,43 atm

ω O2 = 0,022

Tc NO2 = 309,6 K

Pc NO2 = 72,45 atm

ω NO2 = 0,141

Tc H2O = 647,1 K

Pc H2O = 220,5 atm

ω H2O = 0,345

Tc NO = 180,2 K

Pc NO = 64,8 atm

ω NO = 0,583

$$\text{Tr N2} = \frac{40+273}{126,2} = 2,4802 \qquad \text{Tr H2O} = \frac{200+273}{647,1} = ,7310$$

$$\text{Pr N2} = \frac{9.37}{34} = 0,29 \qquad \text{Pr H2O} = \frac{9,37}{220,5} = 0,0447$$

$$\text{Tr O2} = \frac{40+273}{154,6} = 2,0246 \qquad \text{Tr NO} = \frac{40+273}{180,2} = 1,7370$$

$$\text{Pr O2} = \frac{9.37}{50,43} = 0,1955 \qquad \text{Pr NO} = \frac{9.37}{64,8} = 0,1448$$

$$\text{Tr NO2} = \frac{40+273}{309,6} = 1,0110$$

$$\text{Pr NO2} = \frac{9.37}{72,45} = 1,2473$$

Dari Smith Van Ness app B:

$$\frac{(H^R)^0}{RT_c}_{N2} = \text{-0.0491} \qquad \frac{(H^R)^0}{RT_c}_{H2O} = \text{- 0,5512}$$

$$\frac{(H^R)^1}{RT_c}_{N2} = 0,0336 \qquad \frac{(H^R)^1}{RT_c}_{H2O} = \text{-0,8869}$$

$$\frac{(H^R)^0}{RT_c}_{O2} = \text{-0.0427} \qquad \frac{(H^R)^0}{RT_c}_{NO} = \text{-0,0528}$$

$$\frac{(H^R)^1}{RT_c}_{O2} = 0,0139 \qquad \frac{(H^R)^1}{RT_c}_{NO} = 0,0019$$

$$\frac{(H^R)^0}{RT_c}_{NO2} = \text{-0,1324}$$

$$\frac{(H^R)^1}{RT_c}_{NO} = \text{-0,1165}$$

$$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right). R. T_c$$

$(H^R)_{N2}$ = ((-0,0491 + (0,038. 0,0336)). 8,314 . 126,2) / 4,2

= -11,9470 kkal/kmol

= -11,9470 kkal/kmol x 414,6227 kmol = -4953,4961 kkal

$(H^R)_{O2}$ = ((-0,0427 + (0,022. 0,0139)). 8,314 . 154,6) / 4,2

= -12,9741 kkal/kmol

= -12,9741 kkal/kmol x 20,2845 kmol = -263,1724 kkal

$(H^R)_{H2O}$ = ((-0,5512 + 0,345. (-0,8869)). 8,314 . 647,1) / 4,2

= -1098,0052 kkal/kmol

= -1098,0052 kkal/kmol x 4,7210 kmol = -5183,7121 kkal

$(H^R)_{NO}$ = ((-0,0528 + (0,583. 0,0019)). 8,314 .180,2) / 4,2

= -18,4392 kkal/kmol

= -18,4392 kkal/kmol x 1,4692 kmol = -27,0911 kkal

$(H^R)_{NO2}$ = ((-0,1324 + (0,141. -0,1165)). 8,314 .180,2) / 4,2

= -91,2099 kkal/kmol

= -91,2099 kkal/kmol x 28,6299 kmol = -2611,3328 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2}$ = 43535,3865 – 4953,4961 = 516563,9368 kkal

$H_{O2} = H_{igO2} + (H^R)_{O2}$ = 2142,0398 – 263,1724 = 1878,8675 kkal

$H_{H2O} = H_{igH2O} + (H^R)_{H2O}$ = 573,6048 – 5183,7121 = -4610,1074 kkal

$H_{NO} = H_{igNO} + (H^R)_{NO}$ = 152,0637 – 27,0911 = 124,9726 kkal

$H_{NO2} = H_{igNO2} + (H^R)_{NO2}$ = 100,7487 – 2611,3328 = 1449,6400 kkal

Total panas masuk = 33465,0391 kkal

Panas keluar :

Suhu gas keluar pada suhu = 40 °C

$$T = \frac{40 + 25}{2} = 32,5 \text{ °C} = 90,5 \text{ °F}$$

Dari Kirk & Othmer tab. 1:

Cp HNO_3 = 0,58 kal / gr °C

Dari Kern fig. 3 :

Cp NO = 0,23 Btu / lb °F = 0,23 kkal / kg °C

Cp H_2O = 0,45 Btu / lb °F = 0,45 kkal / kg °C

Cp NO_2 = 0,0051 Btu / lb °F = 0,0051 kkal / kg °C

Cp N_2 = 0,25 Btu / lb °F = 0,25 kkal / kg °C

Cp O_2 = 0,22 Btu / lb °F = 0,22 kkal / kg °C

H_{igNO} = m * Cp * ΔT = 316,0608 * 0,235 * (40 - 25) = 1090,4096 kkal

H_{igNO2} = m * Cp * ΔT = 65,8488 * 0,0051 * (40 - 25) = 5,0374 kkal

H_{igN2} = m * Cp * ΔT = 11609,4364 * 0,255 * (40 - 25) = 43535,3865 kkal

H_{igO2} = m * Cp * ΔT = 649,1030 * 0,225 * (40 - 25) = 2142,0398 kkal

H_{H2Oliq} = m * Cp * ΔT = 761,5561 * 1 * (40 - 25) = 11423,3416 kkal

H_{HNO3} = m * Cp * ΔT = 1142,3342 * 0,5 * (40 - 25) = 8567,5062 kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K	Tc NO2 = 309,6 K
Pc N2 = 34 atm	Pc NO2 = 72,45 atm
ω N2 = 0,0,038	ω NO2 = 0,141
Tc O2 = 154,6 K	Tc NO = 180,2 K
Pc O2 = 50,43 atm	Pc NO = 64,8 atm

ω O2 = 0,022

ω NO = 0,583

$$\text{Tr N2} = \frac{40+273}{126,2} = 2,4802$$

$$\text{Tr NO2} = \frac{40+273}{309,6} = 1,0110$$

$$\text{Pr N2} = \frac{9.37}{34} = 0,29$$

$$\text{Pr NO2} = \frac{9.37}{72,45} = 1,2473$$

$$\text{Tr O2} = \frac{40+273}{154,6} = 2,0246$$

$$\text{Tr NO} = \frac{40+273}{180,2} = 1,7370$$

$$\text{Pr O2} = \frac{9.37}{50,43} = 0,1955$$

$$\text{Pr NO} = \frac{9.37}{64,8} = 0,1448$$

Dari Smith Van Ness app B:

$$\frac{(H^R)^0}{RT_c}_{N2} = \text{-0.0491}$$

$$\frac{(H^R)^0}{RT_c}_{NO2} = \text{-0,1324}$$

$$\frac{(H^R)^1}{RT_c}_{N2} = 0,0336$$

$$\frac{(H^R)^1}{RT_c}_{NO2} = \text{-0,1165}$$

$$\frac{(H^R)^0}{RT_c}_{O2} = \text{-0.0427}$$

$$\frac{(H^R)^0}{RT_c}_{NO} = \text{-0,0528}$$

$$\frac{(H^R)^1}{RT_c}_{O2} = 0,0139$$

$$\frac{(H^R)^1}{RT_c}_{NO} = 0,0019$$

$$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right) . R . T_c$$

$(H^R)_{N2}$ = ((-0,0491 + (0,038. 0,0336)). 8,314 . 126,2) / 4,2

= -11,9470 kkal/kmol

= -11,9470 kkal/kmol x 414,6227 kmol = -4953,4961 kkal

$(H^R)_{O2}$ = ((-0,0427 + (0,022. 0,0139)). 8,314 . 154,6) / 4,2

= -12,9741 kkal/kmol

= -12,9741 kkal/kmol x 20,2845 kmol = -263,1724 kkal

$(H^R)_{NO}$ = ((-0,0528 + (0,583. 0,0019)). 8,314 .180,2) / 4,2

= -18,4392 kkal/kmol

= -18,4392 kkal/kmol x 1,4692 kmol = -27,0911 kkal

$(H^R)_{NO2}$ = ((-0,1324 + (0,141. -0,1165)). 8,314 .180,2) / 4,2

= -91,2099 kkal/kmol

= -91,2099 kkal/kmol x 1,4315 kmol = -130,5666 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2}$ = 43535,3865 – 4953,4961 = 516563,9368 kkal

$H_{O2} = H_{igO2} + (H^R)_{O2}$ = 2142,0398 – 263,1724 = 1878,8675 kkal

$H_{NO} = H_{igNO} + (H^R)_{NO}$ = 152,0637 – 27,0911 = 124,9726 kkal

$H_{NO2} = H_{igNO2} + (H^R)_{NO2}$ = 5,0374 – 130,5666 = -125,5292 kkal

H_{NHO3} = 8567,5062 kkal

H_{H2Oliq} = 11423,3416 kkal

Total panas keluar = 61222,2228 kkal

Panas masuk = panas keluar + panas reaksi + Q

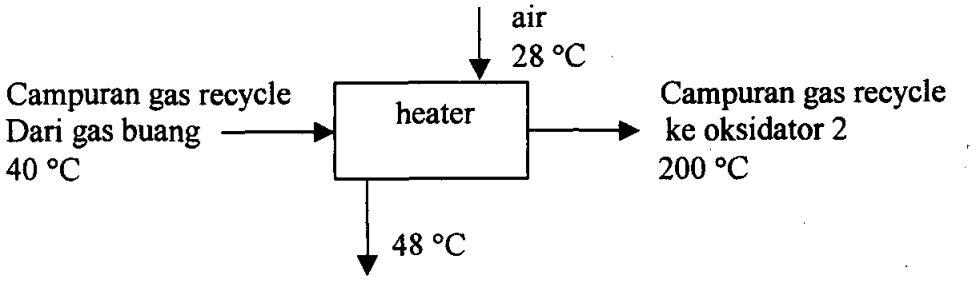
33465,0391 = 61222,2228 – 881229,2102 + Q

Q = 853472,0264 kkal / jam

Neraca panas:

Masuk	kkal / jam	Keluar	kkal / jam
Panas bahan	33465,0391	Panas bahan	61222,2228
Panas reaksi	880129,0154	Panas diserap	853472,0264
Total	913594,0545		913594,0545

7. Heater (E – 232)



Panas masuk :

Suhu masuk = 40 °C

$$T = \frac{40 + 25}{2} = 32,5 \text{ °C} = 90,5 \text{ °F}$$

Dari Kern fig. 3 :

Cp NO = 0,23 Btu / lb °F = 0,23 kkal / kg °C

Cp NO_2 = 0,0051 Btu / lb °F = 0,0051 kkal / kg °C

Cp N_2 = 0,25 Btu / lb °F = 0,25 kkal / kg °C

Cp O_2 = 0,22 Btu / lb °F = 0,22 kkal / kg °C

H_{igNO} = m * Cp * ΔT = 316,0608 * 0,235 * (40 - 25) = 1090,4096 kkal

H_{igNO2} = m * Cp * ΔT = 65,8488 * 0,0051 * (40 - 25) = 5,0374 kkal

H_{igN2} = m * Cp * ΔT = 11609,4364 * 0,255 * (40 - 25) = 43535,3865 kkal

H_{igO2} = m * Cp * ΔT = 649,1030 * 0,225 * (40 - 25) = 2142,0398 kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K

Pc N2 = 34 atm

ω N2 = 0,0,038

Tc O2 = 154,6 K

Pc O2 = 50,43 atm

ω O2 = 0,022

$Tr\ N2 = \frac{40+273}{126,2} = 2,4802$

$Pr\ N2 = \frac{9.37}{34} = 0,29$

$Tr\ O2 = \frac{40+273}{154,6} = 2,0246$

$Pr\ O2 = \frac{9.37}{50,43} = 0,1955$

Tc NO2 = 309,6 K

Pc NO2 = 72,45 atm

ω NO2 = 0,141

Tc NO = 180,2 K

Pc NO = 64,8 atm

ω NO = 0,583

$Tr\ NO2 = \frac{40+273}{309,6} = 1,0110$

$Pr\ NO2 = \frac{9.37}{72,45} = 1,2473$

$Tr\ NO = \frac{40+273}{180,2} = 1,7370$

$Pr\ NO = \frac{9.37}{64,8} = 0,1448$

Dari Smith Van Ness app B:

$\frac{(H^R)^0}{RT_c}_{N2} = -0.0491$

$\frac{(H^R)^1}{RT_c}_{N2} = 0,0336$

$\frac{(H^R)^0}{RT_c}_{O2} = -0.0427$

$\frac{(H^R)^0}{RT_c}_{NO2} = -0,1324$

$\frac{(H^R)^1}{RT_c}_{NO2} = -0,1165$

$\frac{(H^R)^0}{RT_c}_{NO} = -0,0528$

$\frac{(H^R)^1}{RT_c}_{O2} = 0{,}0139$ $\frac{(H^R)^1}{RT_c}_{NO} = 0{,}0019$

$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right)$. R. T_c

$(H^R)_{N2}$ = ((-0,0491 + (0,038. 0,0336)). 8,314 . 126,2) / 4,2

= -11,9470 kkal/kmol

= -11,9470 kkal/kmol x 414,6227 kmol = -4953,4961 kkal

$(H^R)_{O2}$ = ((-0,0427 + (0,022. 0,0139)). 8,314 . 154,6) / 4,2

= -12,9741 kkal/kmol

= -12,9741 kkal/kmol x 20,2845 kmol = -263,1724 kkal

$(H^R)_{NO}$ = ((-0,0528 + (0,583. 0,0019)). 8,314 .180,2) / 4,2

= -18,4392 kkal/kmol

= -18,4392 kkal/kmol x 1,4692 kmol = -27,0911 kkal

$(H^R)_{NO2}$ = ((-0,1324 + (0,141. -0,1165)). 8,314 .180,2) / 4,2

= -91,2099 kkal/kmol

= -91,2099 kkal/kmol x 1,4315 kmol = -130,5666 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2}$ = 43535,3865 – 4953,4961 = 516563,9368 kkal

$H_{O2} = H_{igO2} + (H^R)_{O2}$ = 2142,0398 – 263,1724 = 1878,8675 kkal

$H_{NO} = H_{igNO} + (H^R)_{NO}$ = 152,0637 – 27,0911 = 124,9726 kkal

$H_{NO2} = H_{igNO2} + (H^R)_{NO2}$ = 5,0374 – 130,5666 = -125,5292 kkal

Total panas masuk = 518442,2477 kkal

Panas keluar :

Suhu keluar pada = 200 °C

$$T = \frac{200+25}{2} = 112{,}5\ ^\circ C = 234{,}5\ ^\circ F$$

Dari Kern fig. 3 :

Cp NO = 0,235 Btu / lb °F = 0,235 kkal / kg °C

Cp NO_2 = 0,0104 Btu / lb °F = 0,0104 kkal / kg °C

Cp N_2 = 0,25 Btu / lb °F = 0,25 kkal / kg °C

Cp O_2 = 0,225 Btu / lb °F = 0,225 kkal / kg °C

H_{igNO} = m * Cp * ΔT = 316,0608 * 0,235 * (200 - 25) = 12721,4455 kkal

H_{igNO2} = m * Cp * ΔT = 65,8488 * 0,0051 * (200 - 25) = 58,7701 kkal

H_{igN2} = m * Cp * ΔT = 11609,4364 * 0,255 * (200 - 25) = 507912,8424 kkal

H_{igO2} = m * Cp * ΔT = 649,1030 * 0,225 * (200 - 25) = 24990,4646 kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K

Pc N2 = 34 atm

ω N2 = 0,0,038

Tc O2 = 154,6 K

Pc O2 = 50,43 atm

ω O2 = 0,022

$$Tr\ N2 = \frac{200+273}{126{,}2} = 3{,}1632$$

$$Pr\ N2 = \frac{9.5}{34} = 0{,}29$$

$$Tr\ O2 = \frac{200+273}{154{,}6} = 1{,}7659$$

Tc NO2 = 309,6 K

Pc NO2 = 72,45 atm

ω NO2 = 0,141

Tc NO = 180,2 K

Pc NO = 64,8 atm

ω NO = 0,583

$$Tr\ NO2 = \frac{200+273}{309{,}6} = 1{,}5278$$

$$Pr\ NO2 = \frac{9.5}{72{,}45} = 1{,}2473$$

$$Tr\ NO = \frac{200+273}{180{,}2} = 1{,}5150$$

$$\text{Pr O2} = \frac{9.5}{50,43} = 0,1955 \qquad \text{Pr NO} = \frac{9.5}{64,8} = 0,1448$$

Dari Smith Van Ness app B:

$$\frac{(H^R)^0}{RT_c}_{N2} = -0.0162 \qquad \frac{(H^R)^0}{RT_c}_{NO2} = -0,0605$$

$$\frac{(H^R)^1}{RT_c}_{N2} = 0,0434 \qquad \frac{(H^R)^1}{RT_c}_{NO2} = -0,0097$$

$$\frac{(H^R)^0}{RT_c}_{O2} = -0.0204 \qquad \frac{(H^R)^0}{RT_c}_{NO} = -0,0227$$

$$\frac{(H^R)^1}{RT_c}_{O2} = 0,0271 \qquad \frac{(H^R)^1}{RT_c}_{NO} = 0,0092$$

$$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right) . R . T_c$$

$(H^R)_{N2}$ = ((-0,0162 + (0,038. 0,0434)). 8,314 . 126,2) / 4,2

= -3,6350 kkal/kmol

= -3,6350 kkal/kmol x 414,6227 kmol = -1507,1624 kkal

$(H^R)_{O2}$ = ((-0,0204 + (0,022. 0,0271)). 8,314 . 154,6) / 4,2

= -6,0606 kkal/kmol

= -6,0606 kkal/kmol x 20,2845 kmol = -122,9369 kkal

$(H^R)_{NO}$ = ((-0,0227 + (0,583. 0,0092)). 8,314 .180,2) / 4,2

= -6,1841 kkal/kmol

= -6,1841 kkal/kmol x 1,4692 kmol = -65,1514 kkal

$(H^R)_{NO2}$ = ((-0,0605 + (0,141. -0,0097)). 8,314 .180,2) / 4,2

= -37,9163 kkal/kmol

= -37,9163 kkal/kmol x 1,4315 kmol = -130,5666 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2} = 43535,3865 - 1507,1624 = 42028,2241$ kkal

$H_{O2} = H_{igO2} + (H^R)_{O2} = 24990,4646 - 122,9369 = 2019,1029$ kkal

$H_{NO} = H_{igNO} + (H^R)_{NO} = 12721,4455 - 65,1514 = 1025,2582$ kkal

$H_{NO2} = H_{igNO2} + (H^R)_{NO2} = 58,7701 - 130,5666 = -125,5292$ kkal

Total panas keluar = 543803,9725 kkal

Panas masuk + Q = panas keluar + panas hilang

41231,3750 + Q = 543803,9725 + (0,05 * 41231,3750)

Q = 531193,8592

Kebutuhan steam :

λ = 1940,75 kj / kg

$$m = \frac{Q}{\lambda}$$

$$m = \frac{531193,8592}{1940,75}$$

m = 273,7055 kg / jam

Neraca panas :

Masuk	kkal / jam	Keluar	kkal / jam
Panas bahan	41231,3750	Panas bahan	543803,9725
Panas disuplai	531193,8592	Panas yang hilang	28621,2617
Total	572425,2342		572425,2342

8. Kompresor (G-121 & G-122)

Udara masuk pada suhu = 30 °C

Suhu rata-rata = (30 + 25)/ 2 = 27,5 °C

Massa N2 masuk = 5790,6573 kg / jam = 206,8092 kmol/jam

Massa O2 masuk = 1759,1870 kg/jam = 54,9746 kmol/jam

Massa H_2O masuk = 132,1223 kg / jam = 7,3401 kmol/jam

Dari Kern fig. 3 :

Cp N2 = 0,23 Btu / lb °F = 0,23 kkal / kg °C

Cp O2 = 0,21 Btu / lb °F = 0,21 kkal / kg °C

Cp H_2O = 0,44 Btu / lb °F = 0,44 kkal / kg °C

H_{N2} = m * Cp * ΔT = 5790,6573 * 0,23 * (30 - 25)= 665,2559 kkal

H_{O2} = m * Cp * ΔT = 1759,1870 * 0,21 * (30 - 25)= 1847,1464 kkal

H_{H2O} = m * Cp * ΔT = 132,1223 * 0,44 * (30 - 25)= 290,6691 kkal

Total panas masuk = 2803,0714 kkal

Udara keluar pada suhu = 306,25°C

Suhu rata-rata = (306,25 + 25)/ 2 = 185,62°C

Dari Kern fig. 3 :

Cp N2 = 0,26 Btu / lb °F = 0,26 kkal / kg °C

Cp O2 = 0,23 Btu / lb °F = 0,23 kkal / kg °C

Cp H_2O = 0,46 Btu / lb °F = 0,46 kkal / kg °C

$H_{ig\ N2}$ = m * Cp * ΔT = 5790,6573 * 0,26 * (306,25 - 25)= 423435,6523 kkal

$H_{ig\ O2}$ = m * Cp * ΔT = 1759,1870 * 0,23 * (306,25 - 25)= 113795,7547 kkal

$H_{ig\ H2O}$ = m * Cp * ΔT = 132,1223 * 0,46 * (306,25 - 25)= 17093,0706 kkal

Dari Smith Van Ness app.B

Tc N2 = 126,2 K

Pc N2 = 34 atm

ω NH2 = 0,0,038

Tc O2 = 154,6 K

Pc O2 = 50,43 atm

ω O2 = 0,022

Tc H2O = 647,1 K

Pc H2O = 220,5 atm

ω H2O = 0,345

$$\text{Tr N2} = \frac{306,25 + 273}{126,2} = 4,5899$$

$$\text{Tr H2O} = \frac{306,25 + 273}{647,1} = 0,8951$$

$$\text{Pr N2} = \frac{9.86}{34} = 0,29$$

$$\text{Pr H2O} = \frac{9,86}{220,5} = 0,0447$$

$$\text{Tr O2} = \frac{306,25 + 273}{154,6} = 3,7467$$

$$\text{Pr O2} = \frac{9.86}{50,43} = 0,1955$$

Dari Smith Van Ness app B:

$$\left(\frac{(H^R)^0}{RT_c}\right)_{N2} = -0,0023$$

$$\left(\frac{(H^R)^0}{RT_c}\right)_{H2O} = -0,0533$$

$$\left(\frac{(H^R)^1}{RT_c}\right)_{N2} = 0,0237$$

$$\left(\frac{(H^R)^1}{RT_c}\right)_{H2O} = -0,0641$$

$$\left(\frac{(H^R)^0}{RT_c}\right)_{O2} = -0,0018$$

$$\left(\frac{(H^R)^1}{RT_c}\right)_{O2} = 0,0308$$

$$(H^R) = \left(\frac{(H^R)^0}{RT_c} + \omega . \frac{(H^R)^1}{RT_c} \right) . R . T_c$$

$(H^R)_{N2}$ = ((-0,0023 + 0,038. 0,0237). 8,314 . 126,2) / 4,2

= -0,3496 kkal/kmol

= -0,3496 kkal/kmol x 206,6092 kmol = -72,2989 kkal

$(H^R)_{O2}$ = ((-0,0118 + 0,022. 0,0308). 8,314 . 154,6) / 4,2

= -3,4038 kkal/kmol

= -3,4038 kkal/kmol x 54,9746 kmol = -187,1245 kkal

$(H^R)_{H2O}$ = ((-0,0533 + 0,345. (–0,0641)). 8,314 . 647,1) / 4,2

= -96,6022 kkal/kmol

= -96,6022 kkal/kmol x 7,3401 kmol = -709,0723 kkal

$H_{N2} = H_{igN2} + (H^R)_{N2}$ = 423435,6523 + -72,2989 = 423363,3534 kkal

$H_{O2} = H_{igO2} + (H^R)_{O2}$ = 113795,7547 + -187,1245 = 113608,6301 kkal

$H_{H2O} = H_{igH2O} + (H^R)_{H2O}$ = 17093,0706 + -96,6022 = 16383,9983 kkal

Total panas keluar = 548547,4660 kkal

Panas masuk = panas keluar + Q

2803,0714 = 548547,4660 + Q

Q = 548351,7709 kkal

Neraca panas :

Masuk	kkal / jam	Keluar	kkal / jam
Panas bahan	2803,0714	Panas bahan	548547,4660
Panas karena kompresi	548351,7709		
Total	548547,4660		548547,4660

PERPUSTAKAAN Universitas Katolik Widya Mandala SURABAYA

APPENDIKS C
SPESIFIKASI ALAT

1. FILTER UDARA (H-120)

   Fungsi : untuk menghilangkan debu dalam udara masuk

   Tipe : bag filter

   Kapasitas filter = 400 – 1800 lb/ft^{2}hari (Perry 3^{ed}, hal 990)

   Diambil kapasitas 1800 lb/ft^2 hari

   Rate udara masuk = 7681,9666 kg/jam = 16935,5523 lb/jam

   $$\text{Flow area} = \frac{rate\_udara\_x\_24\,jam}{kapasitas\_filter} = \frac{16935{,}5523..24}{1800} = 225{,}8074 \text{ ft}^2$$

   Spesifikasi :

   Tipe : bag filter

   Kapasitas : 1800 lb/ft^{2}hari

   Flow area : 225,8074 ft^2

2. TANKI PENAMPUNG NH_3 (F-110)

   Fungsi : untuk menyimpan NH3 dalam bentuk cair selama 1 minggu

   Bentuk : tanki silinder vertikal dengan tutup elliptical dished head

   Kondisi operasi : T = 30° C

   P = 11 atm (Perry 7^{ed}, hal 2-88)

   Kebutuhan NH3 = 428,9937 kg/ jam = 945,7533 lb/jam

   Pada P = 1 atm :

   Sv NH3 liq = 1,648.10^{-3} m^3/kg (Perry 7ed, hal 2-214)

   ρ NH3 = 1/sv = 1/ 1,648.10^{-3} = 606,7961 kg/m^3

   ρ H2O = 995,6470 kg/m^3 (Perry 7ed, hal 2-91)

   $$\frac{1}{\rho_{.laR..NH3}} = \frac{0{,}995}{606{,}7961} + \frac{0{,}005}{995{,}647} = 1{,}6448.10^{-3}$$

   $\rho_{\text{lar NH3}}$ = 607,9833 kg/m^3 = 37,9319 lb/ft^3

Direncanakan untuk persediaan 7 hari (168 jam)

maka volume larutan dalam tanki:

$$\text{volume} = \frac{945,7533}{37,9319}.\ 168 = 4188,7318\ \text{ft}^3/\text{tanki}$$

volume cairan = 80% volume tanki

volume tanki = (100/80).4188,7318 = 5235,9148 ft^3

Direncanakan $\frac{L}{D} = 1,5$

$$V = L\ (\frac{\pi.D^2}{4})$$

$$5235,9148 = \frac{1,5}{4}\pi.D^3$$

$$= \left(\frac{1,5}{4}\pi\right)D^3$$

D^3 = 3638,1574

D = 15,3801 ft = 184,5618 in

L = 1,5 x 184,5618 = 276,8427 in

Menghitung Tebal Shell

$$P = 14,7\ \text{psia} = 161,7+(\rho.\frac{g}{gc}.h) = 14,7 + (37,9319.\frac{1}{144}.0,8.23,0702)$$

$$= 166,6\ \text{psig}$$

P design = 1,2 x 166,6 = 199,9 psig

Direncanakan :

- bahan konstruksi stainless steel
- bentuk head eliptical dished head

Dari tabel 13.1, Brownel & Young :

F allowable = 18750 lb/in^2

ε = 85%

$$ts = \frac{P..ri}{f.\varepsilon - 0,6.P}$$ (Brownel & Young, pers 13.1)

$$= \frac{199,9.\frac{184,5618}{2}}{18750..0,85 - .0,6.199,9}$$

$$= 1,1662 = 1\frac{1}{8} \text{ in}$$

Menghitung Tebal Head

Direncanakan :

- bahan konstruksi stainless steel SS
- bentuk head eliptical dished head

Harga k = 2 (Brownel & Young, hal 133)

V = 1/6 (2 + k^2)

= 1/6 (2 + 2^2) = 1

$$th = \frac{P..d..v}{2f.\varepsilon - 0,2.P}$$

$$= \frac{199,9..184,5618}{2..18750.0,85 - 1,2..199,9}$$

= 1,1662 in

$$= 1\frac{1}{8} \text{ in}$$

Mengitung kedalaman head & panjang tanki

Dari tabel 5.11

sf = 3 in

tinggi head = (lD/4) + sf + t

$$= \frac{184,5618}{4} + 3 + 1,1662$$

= 50,3067 in

= 4,1922 ft

tinggi head = b + sf + t = 2 + 133,1447 + 0,3658 = 135,5105 in

= 11,2925 ft

Spesifikasi :

Bahan	: stainless steel
Kapasitas	: 5235,9148 ft^3
Diameter	: 15,3801 ft
Tinggi tanki total	: 31,4546 ft
Tinggi tutup atas	: 4,1922 ft
Tinggi tutup bawah	: 14,1925 ft
Tebal shell	: $1\frac{1}{8}$ in
Tebal tutup atas	: $1\frac{1}{8}$ in
Tebal tutup bawah	: $1\frac{1}{8}$ in
Jumlah	: 1 tanki

3. COMPRESOR

Fungsi : menaikkan tekanan udara dari tekanan 1 atm ke 9,86 atm

Tipe : centrifugal compressor

Perhitungan :

Tekanan masuk : 1 atm = 2116,228 lbf/ft^2

Tekanan keluar : 9,86 atm = 20866,0081 lbf/ft^2

Pressure ratio = 9,86/1 = 9,86

Digunakan kompresor multi-stage karena ratio tekanan lebih besar dari 4

(Ulrich, 1984)

$(r_{p,I})^q = r_{p,T}$ dimana : q = jumlah stage

$(r_{p,I})^2 = 9,86$ $r_{p,I}$ = tekanan keluar tiap stage

$(r_{p,I}) = 3,14$ $r_{p,T}$ = pressure ratio

Rasio kompresi per stage = 3,14

$$T2 = T1 \left(\frac{P_2}{P_1}\right)^{(\gamma-1)/\gamma}$$ dimana : T2 = suhu keluar stage 1

$$T2 = 303 \left(\frac{3,14}{1}\right)^{(1,395-1)/1,395}$$ T1 = suhu masuk stage 1

T2 = 418,94 K = 145,94 °C

COMPRESOR STAGE 1 (G-121)

$$Hp = \frac{3,03.10^{-5}.k}{k-1}.P_1.q_{fm}.\left(\left(\frac{P_2}{P_1}\right)^{(k-1)/k} - 1\right)$$ (Peters 4ed, pers.14-27)

Dimana :

k = Cp/Cv udara = 1,395

P_1 = tekanan udara masuk, lbf/ft^2

P_2 = tekanan udara keluar , lbf/ft^2

q_{fm} = kecepatan volume gas pada kondisi masuk, ft^3/min

ρ pada 30°C = 0,0808 lb/ft^3 (Perry 6ed, table 3-30)

rate udara masuk = 7681,9666 kg/jam = 16935,5523 lb/jam

$$q_{fm} = \frac{16935,5523}{0,0808} = 209598,4196 \text{ ft}^3\text{/jam} = 3493,3070 \text{ ft}^3\text{/min}$$

$$hp = \frac{3,03.10^{-5}.1,395}{1,395-1}.2116,228..3493,3070.(3,14^{(0,395/1,395)} - 1)$$

$= 302,6942$

Efisiensi motor = 70% (Peters 4ed, hal 524)

$$\text{Hp motor} = \frac{302,6942}{0,7} = 432,4203 \text{ hp}$$

Spesifikasi :

Tipe : centrifugal compressor

Pressure ratio = 3,14

Daya motor = 432,4203 hp

Bahan : stainless steel

COMPRESOR STAGE 2 (G-122)

Tekanan udara masuk stage 2 = 3,14 atm = 6644,9559 lbf/ft^2

$$T2 = T1 \left(\frac{P_2}{P_1}\right)^{(\gamma-1)/\gamma}$$ dimana : T2 = suhu keluar stage 2

$$T2 = 418,94 \left(\frac{9,86}{3,14}\right)^{(1,395-1)/1,395}$$ T1 = suhu masuk stage 2

T2 = 579,25 K = 306,25 °C

ρ pada 306,25 ^{0}C = 0,2537 lb/ft^3

rate udara masuk = 7681,9666kg/jam = 16935,5523 lb/jam

$$q_{fm} = \frac{16935,5523}{0,0523} = 323815,5315 \text{ ft}^3\text{/jam} = 5396,9255 \text{ ft}^3\text{/min}$$

$$hp = \frac{3,03.10^{-5}.1,395}{1,395-1}.6644,9559..5396,9255.(3,14^{(0,395/1,395)} - 1)$$

$$= 1468,3968$$

Efisiensi motor = 70% (Peters 4^{ed}, hal 524)

Hp motor = (1468,3968 / 0,7) = 2097,71 hp

Spesifikasi :

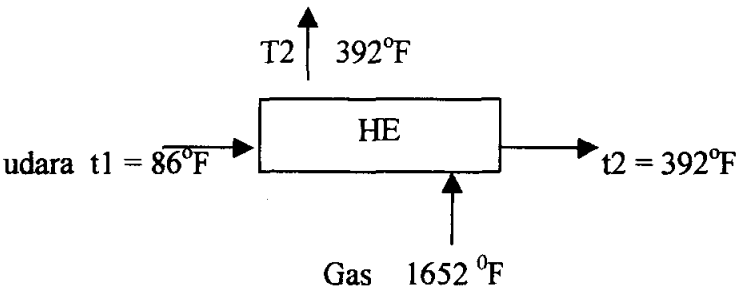
Tipe : centrifugal compressor

Pressure ratio : 3,14

Daya motor : 2097,71 hp

Bahan : stainless steel

4 .HEAT EXCHANGER (E-212)



Fungsi : untuk mendinginkan udara keluar dari oksidator 1

Tipe : shell and tube

Perhitungan :

Neraca Panas

m gas = 8110,9603 kg/jam = 17904,96313 lb/jam

M udara = 36721,4125 kg/jam = 81062,7208 lb/jam

Q = 1560660,0298 kkal/jam = 613095,353 btu/jam

$$LTMD = \frac{(392-86)-(1652-356)}{\ln\frac{(392-86)}{(1652-356)}} = 685{,}86^{\circ}F$$

$$R = \frac{1652-392}{356-86} = 4{,}67$$

$$S = \frac{356-86}{1652-86} = 0{,}1741$$

$F_T = 0{,}87$ (Kern, fig.18)

$\Delta t = 0{,}87 . 68{,}6 = 596{,}7\ ^{\circ}F$

$Tc = (1652 + 392)/2 = 1022^{\circ}F$

$tc = (86 + 356)/2 = 221^{\circ}F$

Trial $U_D = 20$

$$A = \frac{Q}{U_d.\Delta T} = \frac{6193095{,}353}{20.569{,}7} = 518{,}95$$

Ditetapkan:

OD_{tube} = 1 in, 10 BWG (Kern, table 10)

ID_{tube} = 0,732 in

L = 12 ft

a" = 0,2618 ft^2

$$\text{Jumlah tube} = \frac{A}{a''..L} = \frac{518,95}{0,2618..12} = 165,1851$$

Dari tabel 9 Kern, untuk square pitch

$$P_T = 1\frac{1}{4}\text{ in}$$

Nt standar = 166 buah

Passes = 2

$$ID_{shell} = 21\frac{1}{4}\text{ in}$$

$$U_D \text{ terkoreksi} = \frac{165,1851}{166}.20 = 19,9018$$

Shell, gas

$$C' = P_T - OD = 1\frac{1}{4} - 1 = \frac{1}{4}$$

$$B = \frac{3}{4}.21\frac{1}{4} = 15,9375$$

$$a_s = \frac{ID..c'.B}{144.P_T} = \frac{21\frac{1}{4}.\frac{1}{4}.15,9375}{144.1\frac{1}{4}}$$

$$= 0,4704 \text{ ft}^2$$

$$Gs = \frac{W}{as} = \frac{17904,9634}{0,4704}$$

$$= 38065,0842 \text{ lb/jam ft}$$

Pada Tc = 1022°F

Tube, udara

a't = 0,421 (tabel 10)

$$at = \frac{Nt..a't}{144..n} = \frac{166x0,421}{144x2} = 0,2427 \text{ ft}^2$$

$$Gt = \frac{w}{at} = \frac{81062,7208}{0,2427}$$

$$= 334059,2335 \text{ lb/jam ft}$$

Pada tc = 221°F

μ = 0,0225 . 2,42 = 0,0545 lb/jam ft (fig. 14)

c = 0,25 (fig. 2)

$\mu = 0{,}034.\ 2{,}42 = 0{,}0823$ lb/jam ft (fig. 15)

De = 0,99/12 = 0,0825 (fig. 28)

c = 0,2878 (fig. 3)

k = 0,0369 (tab. 5)

$$Res = \frac{D.Gt}{\mu} = \frac{0{,}0825.38065{,}0842}{0{,}0823}$$

$$= 38157{,}5874$$

jH = 105 (fig. 28)

$$\left(\frac{c.\mu}{k}\right)^{\frac{1}{3}} = \left(\frac{0{,}2878.0{,}0823}{0{,}0369}\right)^{\frac{1}{3}} = 0{,}8626$$

$$\frac{ho}{\phi s} = jH\left(\frac{k}{Ds}\right)\left(\frac{c.\mu}{k}\right)^{\frac{1}{3}}$$

$$= 105\frac{0{,}0369}{0{,}0825}0{,}8626 = 40{,}5108$$

k = 0,0157 (tab. 4)

D = 0,732/12 = 0,061 ft (tab.10)

$$Ret = \frac{D.Gt}{\mu} = \frac{0{,}061.334059{,}2835}{0{,}0545}$$

$$= 373901{,}1604$$

$$\frac{L}{D} = \frac{12}{0{,}061} = 196{,}7213$$

jH = 750 (fig. 24)

$$\left(\frac{c.\mu}{k}\right)^{\frac{1}{3}} = \left(\frac{0{,}25.0{,}0545}{0{,}0157}\right)^{\frac{1}{3}} = 0{,}9538$$

$$\frac{hi}{\phi t} = jH\left(\frac{k}{D}\right)\left(\frac{c.\mu}{k}\right)^{\frac{1}{3}}$$

$$= 750\left(\frac{0{,}0157}{0{,}061}\right)0{,}9538 = 184{,}1147$$

$$\frac{hio}{\phi t} = \frac{hi}{\phi t}.\frac{ID}{OD} = 184{,}1147.\frac{0{,}732}{1}$$

$$= 134{,}7720$$

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

$$= 221 + \frac{40{,}5108}{134{,}7720 + 40{,}5108}(1022 - 221)$$

$$= 406{,}1247^{\circ}F$$

Pada tw = 406,1247°F

$\mu_w = 0{,}0295.x\ 2{,}42 = 0{,}0713$ (fig.15)

pada tw = 406,1247°F

$\mu_w = 0{,}0124.x\ 2{,}42 = 0{,}03$ (fig.14)

$$\phi s = \left(\frac{\mu}{\mu w}\right)^{0,14} = \left(\frac{0,0823}{0,0713}\right)^{0,14} = 1,0203$$

ho = 40,5108 x 1,0203 = 41,3332

$$\phi t = \left(\frac{\mu}{\mu w}\right)^{0,14} = \left(\frac{0,545}{0,03}\right)^{0,14} = 1,5007$$

hio = 134,7720 x 1,5007 = 146,5106

$$U_C = \frac{hio..ho}{hio + ho} = \frac{41,3332..146,5106}{41,3332 + 146,5106} = 32,2382$$

$$Rd = \frac{Uc - U_D}{Uc..U_D} = \frac{32,2382 - 19,9018}{32,2382.19,9018} = 0,019$$ (memenuhi > 0,003)

Perhitungan pressure drop

Shell, gas

Nres = 38157,5874

f = 0,0017 (fig. 29)

$$N+1 = \frac{L}{B}.12 = \frac{12}{15,9375}.12 = 9,0353$$

BM campuran = 26,9112 kg/kmol

$$\rho \text{ gas} = \frac{P.BM}{R.T} = \frac{9,37.26,9112}{0,0821.798}$$

$= 3,8488 \text{ kg/m}^3 = 0,2403 \text{ lb/ft}^3$

$$s = \frac{0,2403}{62,5} = 0,0038$$

$$IDs = 21\frac{1}{4} \text{ in} = 1,7708 \text{ ft}$$

$$\Delta Ps = \frac{f.Gs^2.IDs.(N+1)}{5,22.10^{10}.De.s.\phi s}$$

$$= \frac{0,0017(38157,5874)^2.1,7708.9,0353}{5,22.10^{10}.0,0825.0,0038.1,0203}$$

Tube, udara

Nret = 373901,1604

f = 0,000105 (fig. 26)

ρ udara = 0,0535 lb/ft^3

(Geankoplis, Tabel A-3.3)

s = 0,535/62,5 = 0,0086

$$\Delta Pt = \frac{f.Gt^2.L.n}{5,22.10^{10}.D.s.\phi t}$$

$$= \frac{0,000105(373901,1604)^2.12.2}{5,22.10^{10}.0,061.0,0086.1,5007}$$

=0,8573 psi

$$\frac{v}{2g'} = 0,0013$$ (fig. 27)

$$\Delta Pr = \frac{4n}{s}\frac{v}{2g'}$$

$= \frac{4.6}{0,0086} 0,0013 = 0,6279$ psi

= 2,3732 psi

(memenuhi < 10 psi)

$\Delta P_T = 0,8573 + 0,6279 = 1,4852$ psi

(memenuhi < 2 psi)

Spesifikasi:

Tipe : shell & tube

Shell : ID = $21\frac{1}{4}$ in; baffle space = 15,9375 in; passes = 1

Tube : OD = 1 in; 10 BWG; L = 12 ft; passes = 2; $P_T = 1\frac{1}{4}$ in (square pitch)

Jumlah tube : 166

Ud = 19,9018

Uc = 32,2382

Rd = 0,019

ΔP shell = 2,3732 psi

ΔP tube = 1,4852 psi

5. TANKI PENAMPUNG HNO_3 (F-310)

Fungsi : untuk menyimpan HNO_3 selama 1 hari

Bentuk : tanki silinder horisontal bertekanan 1 atm dengan tutup elliptical dished head

Kondisi operasi : T = 30° C

P = 1 atm

Rate = 1903,8903 kg/ jam = 4197,2890 lb/jam

Pada 1 atm dan 30°C :

Sg HNO3 = 1,504. m^3/kg (Perry 7ed, hal 2-214)

ρ HNO3 = (1,504/1).62,43 = 93,8947 lb/ft^3

ρ H2O = 995,6470 kg/m^3 = 62,1582 lb/ft^3 (Perry 7ed, hal 2-91)

$$\frac{1}{\rho_{\cdot laR..HNO3}} = \frac{0,6}{93,8947} + \frac{0,4}{62,1582} = 0,0128$$

$\rho_{\text{lar HNO3 60\%}} = 1/0{,}0128 = 77{,}9707 \text{ lb/ft}^3$

Direncanakan:

- untuk menampung hasil produksi selama 1 hari
- memakai 1 tanki penyimpan

maka volume larutan dalam tanki:

$$\text{volume} = \frac{4197{,}2890}{77{,}9707}.24 = 1291{,}9589 \text{ ft}^3$$

volume cairan = 80% volume tanki

volume tanki = (100/80).1291,9589 = 1614,9486 ft^3

Direncanakan $\frac{L}{D} = 1{,}5$

$$V = L\ (\frac{\pi.D^2}{4})$$

$$1614{,}9486 = \frac{1{,}5}{4}\pi.D^3$$

$$= \left(\frac{1{,}5}{4}\pi\right)D^3$$

$D^3 = 1371{,}71$

$D = 11{,}1105 \text{ ft} = 133{,}3257 \text{ in}$

$L = 1{,}5 \times 133{,}3257 = 199{,}9885 \text{ in}$

Menghitung Tebal Shell

P = 1 atm = 14,7 psia = 14,7 + (77,9707.(1/144).0,8.16,6657)

= 21,9191 psig

P design = 1,2 x 21,9191 = 26,3029 psig

Direncanakan :

- bahan konstruksi stainless steel SS
- bentuk head eliptical dished head

Dari tabel 13.1, Brownel & Young :

F allowable = 18750 lb/in^2

ε = 85%

$$ts = \frac{P..ri}{f.\varepsilon - 0,6.P}$$ (Brownel & Young, pers 13.1)

$$= \frac{26,3029.\frac{133,3257}{2}}{18750..0,85 - .0,6.26,3029}$$

$$= 0,1101 \text{ in} = \frac{1}{8} \text{ in}$$

Menghitung Tebal Head

Direncanakan :

- bahan konstruksi stainless steel SS
- bentuk head eliptical dished head

Harga k = 2 (Brownel & Young, hal 133)

$V = 1/6 (2 + k^2)$

$= 1/6 (2 + 2^2) = 1$

$$th = \frac{P..d..v}{2f.\varepsilon - 0,2.P}$$

$$= \frac{26,3029..124,6473}{2..18750.0,85 - 0,2..26,3029}$$

$$= 0,1101 \text{ in} = \frac{1}{8} \text{ in}$$

Menghitung tinggi head

tinggi head = t + sf + (ID/4)

dari tabel 5.11

sf = 3 in

$$\text{tinggi head} = 0,11 + 3 + \frac{133,3257}{4}$$

$$= 36,4414 \text{ in}$$

$$= 3,0368 \text{ ft}$$

Menghitung tebal tutup bawah yang berbentuk flat

$t = c.\ D.\ (P/f)^{1/2}$

$t = 133{,}3257.(26{,}3029/18750)^{1/2}$

$= 4{,}9936$ in $= 5$ in

Spesifikasi :

Bahan	: stainless steel
Kapasitas	: 1614,9486 ft^3
Diameter	: 11,1105 ft
Tinggi tanki total	: 24,7025 ft
Tinggi tutup atas	: 3,0368 ft
Tebal shell	: 1/8 in
Tebal tutup atas	: 1/8 in
Tebal tutup bawah	: 5 in
Jumlah	: 1 tanki

6. OKSIDATOR 2 (R-230)

Fungsi : untuk membentuk NO_2 dari NO dan O_2 dalam gas

Tipe : reaktor plug flow

Reaksi : NO + ½ O2 ------- NO2

Konversi reaksi = 95 %

Suhu gas masuk = 200 °C

$$\text{Log } k = \frac{652{,}1}{T} - 1{,}0366 = \frac{652{,}1}{200+273} - 1{,}0366 = 0{,}3420$$

$k = 2{,}1981\ s^{-1}$

$F_{AO} = 526{,}3691$ lbmol / jam

$$C_{AO} = \frac{x.\ P}{R.\ T} = \frac{0{,}1214.\ 9{,}37}{0{,}729.\ 852} = 0{,}0183 \text{ lbmol / ft}^3$$

$\varepsilon_A = 1$

$$V = \frac{F_{AO}}{k.\ C_{AO}}\left((1+\varepsilon_A)\ln\frac{1}{1-x_A} - \varepsilon_A.\ x_A\right)$$

$$= \frac{526{,}3691}{3600.\ 2{,}1981.\ 0{,}00183}\left((1+1)\ln\frac{1}{1-0{,}95} - 1.\ 0{,}.95\right)$$

$= 183{,}2509\ ft^3$

$L = 1{,}5\ D$

$V = (\ 1{,}5/4\ ).\ 3{,}14.\ D^3$

$183{,}2509 = (1{,}5\ /\ 4\ ).\ 3{,}14.\ D^3$

$D = 5{,}3789\ ft = 64{,}547\ in$

$L = 1{,}5 \times 64{,}547 = 96{,}821\ in$

Menghitung tebal shell

P = 137,739 psia = 152,439 psig

P design = 1,2 x 152,439 = 182,93 psig

Direncanakan :

- bahan konstruksi stainless steel SS

Dari tabel 13.1, Brownel & Young :

F allowable = 18750 lb/in^2

ε = 85%

$$ts = \frac{P..ri}{f.\varepsilon - 0{,}6.P}$$ (Brownel & Young, pers 13.1)

$$= \frac{182{,}93.\frac{96{,}821}{2}}{18750..0{,}85 - .0{,}6.182{,}93}$$

$$= 0{,}5595\ in = \frac{5}{8}\ in$$

Menghitung Tebal Head

Direncanakan :

- bahan konstruksi stainless steel SS
- bentuk head eliptical dished head

Harga k = 2 (Brownel & Young, hal 133)

$V = 1/6\ (2 + k^2)$

$= 1/6\ (2 + 2^2) = 1$

$$th = \frac{P..d..v}{2f.\varepsilon - 0,2.P}$$

$$= \frac{182,93..96,821}{2..18750.0,85 - 0,2..182,93}$$

$$= 0,5563 \text{ in} = \frac{5}{8} \text{ in}$$

Menghitung tinggi head

tinggi head = t + sf + (ID/4)

dari tabel 5.11

sf = 3 in

$$\text{tinggi head} = 0,5563 + 3 + \frac{96,821}{4}$$

$= 27,7612$ in

$= 2,3134$ ft

$$G = \frac{W}{as} = \frac{14431,7960}{0,453.\ 0,25.\ 3,14.\ (8,068)^2}$$

$= 623,4774$ lb/jam ft

Pada Tc = 392°F

$\mu = 0,0404.\ 2,42 = 0,0978$ lb/jam ft (fig. 15)

c = 0,2698 (fig. 3)

k = 0,0289 (tab. 5)

$$Res = \frac{D.Gt}{\mu} = \frac{8,068.\ 623,4774}{0,0978}$$

$= 51436,3543$

$$\frac{hi}{\phi} = Nre\left(\frac{k}{D}\right)\left(\frac{c.\mu}{k}\right)^{\frac{1}{3}}$$

$$= 51436,3543\frac{0,0289}{8,068}0,9690 = 178,5360$$

asumsi ϕ =1

hio = hi . (ID/OD)

= 178,5360. (8,068/(8,068 + 0,0466)

= 177,5102

$$U_C = \frac{hio..ho}{hio + ho} = \frac{177,5102.\,178,5360}{177,5102 + 178,5360} = 89,0108$$

Rd = 0,01 (Kern, tabel 12)

$$\frac{1}{Ud} = \frac{1}{Uc} + Rd = \frac{1}{89,0108} + 0,01 = 0,02123$$

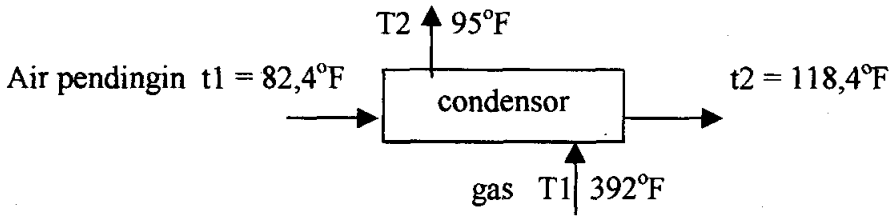
Ud = 47,093

$$A = \frac{Q}{Ud.\Delta T} = \frac{812433,5238}{47,093.\,50} = 345,0339\ ft^2$$

Spesifikasi:

Tipe	: reaktor plug flow
Bahan	: stainless steel
Kapasitas	: 183,2509 ft^3
Diameter	: 8,068 ft
Tinggi tanki total	: 16,7288 ft
Tinggi tutup atas	: 2,3134 ft
Tinggi tutup bawah	: 2,3134 ft
Tebal shell	: 5/8 in
Tebal tutup atas	: 5/8 in
Tebal tutup bawah	: 5/8 in
Jumlah	: 1 tanki

7. CONDENSER (E-232)



Fungsi : untuk mendinginkan gas dari suhu 392°F ke 95°F

Tipe : shell and tube

Perhitungan :

Neraca Panas

m gas = 14431,7980 kg/jam = 31816,1332 lb/jam

M air = 59171,1061 kg/jam = 130447,7648 lb/jam

Q = 1183422,1224 kal/jam = 4696119,532 btu/jam

$$LTMD = \frac{(95-82,4)-(392-118,4)}{\ln\frac{(95-82,4)}{(392-118,4)}} = 84,83\ ^{\circ}F$$

$$R = \frac{392-95}{118,4-82,4} = 8,25$$

$$S = \frac{118,4-82,4}{392-82,4} = 0,0116$$

$F_T = 0,98$ (Kern, fig.18)

$\Delta t = 0,98.\ 84,83 = 83,132\ ^{\circ}F$

$Tc = (392+95)/2 = 243,5\ ^{\circ}F$

$tc = (118,4+82,4)/2 = 100,4\ ^{\circ}F$

Trial $U_D = 30$

$$A = \frac{Q}{U_d.\Delta T} = \frac{4696119,532}{30.\ 84,83} = 1845,3366$$

Ditetapkan:

OD_{tube} = 1 in, 10 BWG (Kern, table 10)

ID_{tube} = 0,732 in

L = 12 ft

a" = 0,2618 ft^2

Jumlah tube = $\frac{A}{a''..L} = \frac{1845,3366}{0,2618..12} = 587,3875$

Dari tabel 9 Kern, untuk square pitch

$P_T = 1\frac{1}{4}$ in

Nt standar = 596 buah

Passes = 1

ID_{shell} = 37 in

U_D terkoreksi = $\frac{587,3875}{596}30 = 29,5665$

Shell, gas

$C' = P_T - OD = 1\frac{1}{4} - 1 = \frac{1}{4}$

$B = \frac{3}{4}.37 = 27,75$

$a_s = \frac{ID..c'.B}{144.P_T} = \frac{37.\ 1/4.\ 27,75}{144.\ 1\frac{1}{4}}$

= 1,4260 ft^2

$Gs = \frac{W}{as} = \frac{31816,1332}{1,4268}$

= 22298,9439 lb/jam ft

Pada Tc = 243,5°F

μ = 0,034. 2,42 = 0,0823 lb/jam ft (fig. 15)

Tube, air

a't = 0,421 (tabel 10)

$at = \frac{Nt..a't}{144..n} = \frac{596x0,421}{144x1}$

= 1,7425 ft^2

$Gt = \frac{w}{at} = \frac{130447,4648}{1,7425}$

= 74862,2457 lb/jam ft

Pada tc = 100,4 °F

μ = 0,0225 . 2,42 = 0,0545 lb/jam ft (fig. 14)

c = 0,25 (fig. 2)

k = 0,0157 (tab. 4)

D = 0,732/12 = 0,061 ft (tab.10)

De = 0,99/12 = 0,0825 (fig. 28)

c = 0,2878 (fig. 3)

k = 0,0369 (tab. 5)

$$Res = \frac{D.Gt}{\mu} = \frac{0,0825\ .22311,4539}{0,0823}$$

$$= 22365,6737$$

jH = 150 (fig. 28)

$$\left(\frac{c.\mu}{k}\right)^{\frac{1}{3}} = \left(\frac{0,2878.0,0823}{0,0369}\right)^{\frac{1}{3}} = 0,8626$$

$$\frac{ho}{\phi s} = jH\left(\frac{k}{Ds}\right)\left(\frac{c.\mu}{k}\right)^{\frac{1}{3}}$$

$$= 150\frac{0,0369}{0,0825}0,8626 = 57,8726$$

$$Ret = \frac{D.Gt}{\mu} = \frac{0,061.\ 74862,2467}{0,0545}$$

$$= 83790,7715$$

$$\frac{L}{D} = \frac{12}{0,061} = 196,7213$$

jH = 400 (fig. 24)

$$\left(\frac{c.\mu}{k}\right)^{\frac{1}{3}} = \left(\frac{0,25.0,0545}{0,0157}\right)^{\frac{1}{3}} = 0,9538$$

$$\frac{hi}{\phi t} = jH\left(\frac{k}{D}\right)\left(\frac{c.\mu}{k}\right)^{\frac{1}{3}}$$

$$= 400\left(\frac{0,0157}{0,061}\right)0,9538 = 98,1945$$

$$\frac{hio}{\phi t} = \frac{hi}{\phi t}.\frac{ID}{OD} = 98,1945.\frac{0,732}{1}$$

$$= 71,8784$$

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

$$= 100,4 + \frac{57,8726}{71,8784 + 57,8726}(243,5\text{-}100,4)$$

$$= 164,23°F$$

Pada tw = 189,54°F

μ_w = 0,0264.x 2,42 = 0,064 (fig.15)

pada tw = 189,54°F

μ_w = 0,0196.x 2,42 = 0,0474 (fig.14)

$$\phi s = \left(\frac{\mu}{\mu w}\right)^{0,14} = \left(\frac{0,034}{0,064}\right)^{0,14} = 0,9153$$

$$\phi t = \left(\frac{\mu}{\mu w}\right)^{0,14} = \left(\frac{0,0545}{0,0474}\right)^{0,14} = 1,0196$$

ho = 57,8726 x 0,9153 = 52,9708

hio = 71,8784 x 1,0196 = 73,2872

$$U_C = \frac{hio..ho}{hio + ho} = \frac{52,9708..73,2872}{52,9708 + 73,2872} = 30,7472$$

$$Rd = \frac{Uc - U_D}{Uc..U_D} = \frac{30,7472 - 29,5665}{30,7472\ .29,5665} = 0,0031 \quad \text{(memenuhi > 0,003)}$$

Perhitungan pressure drop

Shell, gas

Nres = 22365,6737

f = 0,0016 (fig. 29)

$$N+1 = \frac{L}{B}.12 = \frac{12}{27,75}.12 = 5,1825$$

BM campuran = 28,4158 kg/kmol

$$\rho \text{ gas} = \frac{P.BM}{R.T} = \frac{9,37.28,4158}{0,0821.516,5}$$

$$= 6,2789 \text{ kg/m}^3 = 0,3917 \text{ lb/ft}^3$$

$$s = \frac{0,3917}{62,5} = 0,0063$$

IDs = 37 in = 3,0833 ft

$$\Delta Ps = \frac{f.Gs^2.IDs.(N+1)}{5,22.10^{10}.De.s.\phi s}$$

$$= \frac{0,0016(22365,6737)^2.3,0833.5,1892}{5,22.10^{10}.0,0825.0,0063.0,9153}$$

Tube, air

Nret = 83790,7715

f = 0,00011 (fig. 26)

ρ air = 62,5 lb/ft^3

(Geankoplis, Tabel A-3.3)

s = 62,5/62,5 = 1

$$\Delta Pt = \frac{f.Gt^2.L.n}{5,22.10^{10}.D.s.\phi t}$$

$$= \frac{0,000155(83790,7715)^2.12.1}{5,22.10^{10}.0,061.1.1,196}$$

=0,0034 psi

$$\frac{v}{2g'} = 0,001 \quad \text{(fig. 27)}$$

$$\Delta Pr = \frac{4n}{s}\frac{v}{2g'}$$

$$= \frac{4.1}{1}0,004 = 0,016 \text{ psi}$$

= 0,5157 psi
(memenuhi < 10 psi)

$\Delta P_T = 0{,}0021 + 0{,}016 = 0{,}0194$ psi
(memenuhi < 2 psi)

Spesifikasi:

Tipe : shell & tube

Shell : ID = 37 in; baffle space = 27,75 in; passes = 1

Tube : OD = 1 in; 10 BWG; L = 12 ft; passes = 1; $P_T = 1\frac{1}{4}$ in (square pitch)

Jumlah tube : 596

Ud = 29,5665

Uc = 30,7472

Rd = 0,0031

ΔP shell = 0,5157 psi

ΔP tube = 0,0194 psi

8. BAG FILTER (H-220)

Fungsi : untuk mengambil platinum yang terikut pada gas keluar dari oksidator 1

Perhitungan :

Kapasitas filter = 400 – 1800 lb/ft^{2}hari

Diambil kapasitas 1800 lb/ft^{2}hari

Rate gas masuk = 8110,9603 kg/jam = 17881,3058 lb/jam

$$\text{Flow area} = \frac{flow\_area\_x\_24\,jam}{kapasitas\_filter} = \frac{17881{,}3058..24}{1800} = 238{,}4474 \text{ ft}^2$$

Spesifikasi :

Type : bag filter

Kapasitas : 1800 lb/ft^{2}hari

Flow area : 238,4474 ft^2

Jumlah : 1

9. BLOWER 1 (G-231)

Fungsi : untuk mengalirkan gas dari oksidator 1 menuju bag filter

Tipe : centrifugal

Kondisi operasi : T = 400°C

P = 1 atm

BM gas = 27,17 g/mol

ρ gas = P. BM / R. T

= 1.27,17/ 0,0821. 673 = 0,4917 kg/m^3

rate gas = 8110,9603 kg/jam

rate volumetrik = 8110,9603 / 0,4971 = 16316,5566 m^3/jam

= 9603,1094 ft^3/menit

$$hp = \frac{144..qfm.(P_2 - P_1)}{33000}$$ (Perry 5ed, hal 6-20)

$$= \frac{144..9603,1094.(9,5 - 9,37)}{33000}$$

= 5,4476 hp

effisiensi = 75%

power = 5,4476 / 0,75 = 7,2634 hp

Spesifikasi :

Tipe : centrifugal

Rate : 9603,1094 ft^3/menit

Power : 7,2634 hp

Bahan : stainless steel

10. BLOWER 2 (G-241)

Fungsi : untuk mengalirkan gas dari kondensor menuju menara absorber

Tipe : centrifugal

Kondisi operasi : T = 35°C

P = 1 atm

BM gas = 29,1794 g/mol

ρ gas = P. BM / R. T

= 1.29,1794 / 0,0821. 308 = 1,1539 kg/m^3

rate gas = 14431,7960 kg/jam

rate volumetrik = 14431,7960 / 1,1539 = 12506,9726 m^3/jam

= 7360,9789 ft^3/menit

$$hp = \frac{144..qfm.(P_2 - P_1)}{33000}$$ (Perry 5ed, hal 6-20)

$$= \frac{144..7360,9789.(9,5-9,37)}{33000}$$

= 4,1757 hp

effisiensi = 75%

power = 4,1757 / 0,75 = 5,5676 hp

Spesifikasi :

Tipe : centrifugal

Rate : 7360,9786 ft^3/menit

Power : 5,5676 hp

Bahan : stainless steel

11. FURNACE (Q-211)

Fungsi : untuk memanaskan gas yang akan masuk ke oksidator 1

Kondisi operasi :

Suhu gas masuk = 30°C

Suhu udara masuk = 30°C

Suhu fuel oil masuk = 30°C

Suhu gas keluar = 850°C

Suhu flue gas keluar = 1200°C

Panas yang diterima furnace = 1413835,5248 kkal/jam = 5610458,429 btu/jam

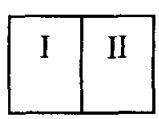
Bahan bakar masuk = 321,3508 kg/jam

Direncanakan dapur berukuran : 10 x 15 x 5 ft

Luas permukaan dinding total = 2(5. 15) + 2(5. 10) + 2(10. 15) = 550 ft^2

Kehilangan panas melalui dinding 20%

Panas yang hilang = 0,2 . 5610458,429 = 1122091,686 btu/jam



T1= 86°F T2 = 1562°F

I. Insulating fire brick

II. Fire clay brick

Suhu rata-rata = (1562 + 86)/2 = 824°F

q = 1122091 / 550 = 20401667 btu/jam ft^2

$hc = c_1 . k . (\alpha . \Delta t)^{1/3}$

α udara = $0,0353.10^6$ $(ft^3\ °F)^{-1}$

k udara = 0,0308btu/jam ft °F

c_1 = 0,13

d = 1/3

hc = 0,13. 0,0308. $(0,0353.10^6 . 1476)^{1/3}$ = 1,4955 btu/jam ft^2°F

$$hr = \frac{\tau.Fe.Fr.(ts^4 - tr^4)}{ts - tr}$$

ts = 1562°F =2022°R

tr = 86°F = 456°R

τ = konstanta Boltzman = $0,173.10^{-8}$

Fr = 1

Fe = 0,75

$$hr = \frac{0,173.10^{-8}.0,75.1.(2022^4 - 546^4)}{2022 - 546} = 20,0391 \text{ btu/jam } ft^2°F$$

ho = hc + hr = 1,4955 + 20,0391 = 21,5346 btu/jam ft^2°F

Dari table 2, Kern :

k insulating fire brick = 0,309 btu/jam ft^{2o}F

k fire clay brick = 0,9125 btu/jam ft^{2o}F

$$q = \frac{t_1 - t_2}{\frac{x}{k_1} + \frac{x}{k_2} + \frac{1}{ho}}$$

$$2040,1667 = \frac{1562 - 86}{\frac{x}{0,0309} + \frac{x}{0,9125} + \frac{1}{21,5346}}$$

x = 0,1563 ft

Digunakan tube dengan ukuran 2"sch 40, dengan panjang 12 ft

Dari table 11, Kern :

ID = 2,067" = 0,1723 ft

OD = 2,38" = 0,1983 ft

a" = 0,622 ft^2

Rate gas masuk = 17881,3058 lb/jam

Dari Kern :

Cp = 0,3011 btu/lb°F (figure 3)

μ = 0,0318 . 2,42 = 0,0769 lb/jam ft (figure 15)

k = 0,0338 btu/jam ft^2(°F/ft) (table 4)

$$G = \frac{rate}{\frac{\pi}{4}D^2} = \frac{17881,3058}{\frac{\pi}{4}0,1723^2} = 767289,0814 \text{ lb/jam ft}^2$$

$$\frac{hi.D}{k} = 0,0115.\left(\frac{D.G}{\mu}\right)^{0,9}\left(\frac{c.\mu}{k}\right)^{0,5}$$ (Kern, pers. 3-42)

$$\frac{hi.0,1723}{0,0338} = 0,0115.\left(\frac{0,1723.17881,3058}{0,0769}\right)^{0,9}\left(\frac{0,3011.0,0769}{0,0338}\right)^{0,5}$$

hi = 36,4448 btu/jam ft^{2o}F

hio = hi .(ID/OD) = 36,4448.(2,067 /2,38) = 31,6518 btu/jam ft^{2o}F

$$Uc = \frac{hio.ho}{hio + ho} = \frac{31{,}6518..36{,}4448}{31{,}6518 + 36{,}4448} = 16{,}9398$$

Dari table 12, Kern :

Rd gas = 0,002

Rd fuel oil = 0,005

Rd gabungan = 0,007

$$\frac{1}{Ud} = \frac{1}{Uc} + Rd = (1/\ 16{,}9398) + 0{,}007 = 0{,}066$$

Ud = 15,144

Q = Ud . A. ΔT

5610458,4290 = 15,144. A. (1562-86)

A = 250,9987 ft^2

A = Nt. a".L

250,9987 = Nt. 0,622. 12

Nt = 33,6279 = 34 buah tube

Spesifikasi :

Ukuran furnace : 5 x 10 x 15 ft

Tebal dinding : 0,1563 ft

Jumlah tube : 34 buah

ID tube : 2,067 in

OD tube : 2,38 in

Panjang tube : 12 ft

Jumlah alat : 1

12. OKSIDATOR 1 (R-210)

Fungsi : untuk mereaksikan NH3 menjadi NO dan H2O dengan katalis platinum- rhodium berbentuk kawat kasa

Kondisi Operasi : suhu : 850°C = 1562°F

Tekanan : 9,37 atm = 137,739 psi

Komposisi gas masuk :

Gas	kg/jam	kmol/jam	fraksi mol
O2	1759,1870	54,9746	0,1868
N2	5790,6573	206,8092	0,7026
H2O	134,2672	7,4593	0,0253
NH3	426,8487	25,1087	0,0853

Reaksi :$NH_3(g) + 5/4\ O_2$ ------ $NO(g) + 3/2\ H_2O(g)$

Konversi reaksi : 99,9% (carberry, sec.10.7)

$X = 1 - \exp(-k.g.a.\theta)$ (carberry, pers.10-128)

$0,999 = 1 - \exp(-k.g.a.\theta)$

$0,001 = \exp(-k.g.a.\theta)$

$\ln 0,001 = -\ k.\ g.\ a.\ \theta$

$k.g.a.\theta = 6,9$

$$k.g.a.\theta = \frac{4.n}{Re^{0,7}}$$ (Carberry, hal 586)

dimana n : jumlah lapisan kawat platinum

Re: Reynold number (10 - 10^4)

Diambil harga Re = 10

$$6,9 = \frac{4.n}{10^{0,7}}$$

$n = 8,6 \approx 9$ buah

Dari figure 15, Kern:

μ NH3 = 0,04. 2,42 = 0,0968 lb/jam ft

μ O2 = 0,051. 2,42 = 0,1234 lb/jam ft

μ H2O = 0,046. 2,42 = 0,1111 lb/jam ft

μ N2 = 0,047. 2,42 = 0,1137 lb/jam ft

μ gas campuran = $(0,0968^{1/3}.0,0871)+(0,1234^{1/3}.0,1908)+(0,1111^{1/3}.0,0043)$
$+(0,1137^{1/3}.0,7178)$
= 0,1141 lb/jam ft

Dari table 3-30, Perry 6^{ed} :

ρ NH3 = 0,0482 lb/ft^2

ρ O2 = 0,0892 lb/ft^2

ρ N2 = 0,0782 lb/ft^2

ρ H2O = 0,91 lb/ft^2

$$\frac{1}{\rho_{campuran}} = \frac{0,0871}{0,0482} + \frac{0,1908}{0,0892} + \frac{0,0043}{0,91} + \frac{0,7178}{0,0782} = 13,1298$$

ρ campuran = 0,0762 lb/ft^2 (pada STP)

$$\rho \text{ campuran pada } 137,739 \text{ psi dan } 1562^oF = \frac{0,0762.(32+460)}{14,7} . \frac{137,739}{(1562+460)}$$

$$= 0,1737 \text{ lb/ft}^2$$

$$V = \frac{\mu}{\rho} = \frac{0,1141}{0,0762} = 1,497 \text{ ft}^3\text{/jam ft}$$

Re = dw . u/V (Carberry, hal 586)

10 = 2,5.10^{-4}. u/1,497

u = 59878 ft/jam = 997,9667 ft/menit

Rate total gas masuk = 294,3518 kmol/jam = 10,8154 lbmol/menit

Volume 1 lbmol pada 137,739 psi dan 1562°F = Vo . (Po/P). (T/To)

= 359. (14,7 / 137,739). (1562+460 / 32+460) = 667,4602 ft^3/lbmol

Rate gas masuk (Q) = 10,8154. 667,4602 = 7218,8194 ft^3/menit

= 433129,1654 ft^3/jam

S = Q/u = 7218,8194 / 997,9667 = 7,2335 ft^2

S = 0,25 π D^2

7,2335 = 0,25. 3,14. D^2

D = 3,0356 ft

Waktu kontak dalam lapisan kawat kasa

$\theta = dw.\ \varepsilon.\ n/V$

dimana ε : void fraction rata-rata , diambil 0,5

$\theta = 2{,}5.10^{-4}.0{,}5.\ 9/1{,}497 = 7{,}515.10^{-4}$ jam^{-1} = 2,7054 det^{-1}

Menghitung tebal shell

P = 137,739 psia = 152,439 psig

P design = 1,2 . 152,439 = 182,9268 psig

Direncanakan :

Bahan konstruksi stainless steel SS

Tabel 13.1, Brownell & Young diperoleh :

f allowable = 18750 lb/in^2

ε = 85%

$$ts = \frac{P..ri}{f.\varepsilon - 0{,}6.P}$$ (Brownel & Young, pers 13.1)

$$= \frac{182{,}9268.\frac{32{,}2972}{2}}{18750..0{,}85 - .0{,}6.182{,}9268}$$

$$= 0{,}1866 = \frac{1}{4} \text{ in}$$

Menghitung tebal head

Direncanakan :

- menggunakan bahan stainless steel SS
- berbentuk elliptical dished head

Harga k = 2 (Brownell hal 133)

$V = 1/6\ (2 + k^2)$

$= 1/6\ (2 + 2^2) = 1$

$$th = \frac{P..d..v}{2f.\varepsilon - 0{,}2.P}$$

$$= \frac{182{,}9268..32{,}2972}{2..18750.0{,}85 - 0{,}2..182{,}9268}$$

$$= 0{,}1856 = \frac{1}{4} \text{ in}$$

Menghitung tinggi head

dari table 5.11 Brownell & Young,

sf = 3 in

tinggi head = t + sf + (ID/4)

= 3 + 0,1856 + (32,2972/4)

= 11,2599 in = 0,9383 ft

Menghitung tinggi shell

Jarak antar kawat = 1 in

Jarak antar kawat dari atas hingga bawah = (9-1). 1 = 8 in = 0,6667 ft

Tinggi ruang kosong diambil (atas + bawah) = 1,5 ft + 1,5 ft = 3 ft

Tinggi shell = 3+ 0,6667 = 3,6667 ft

Menghitung luas perpindahan panas

Pada Tc = 392°F

μ = 0,0404. 2,42 = 0,0978 lb/jam ft (fig. 15)

c = 0,2698 (fig. 3)

k = 0,0289 (tab. 5)

$$Res = \frac{D.Gt}{\mu} = \frac{2{,}6914.17881{,}3058}{0{,}0978}$$

$$= 492083{,}2962$$

$$\frac{hi}{\phi} = Nre\left(\frac{k}{D}\right)\left(\frac{c.\mu}{k}\right)^{\frac{1}{3}}$$

$$= 492083{,}2962\frac{0{,}0289}{2{,}6914}0{,}9690 = 5120{,}1487$$

asumsi ϕ =1

hio steam = 1500 (Kern, hal. 719)

$$U_C = \frac{hio..ho}{hio + ho} = \frac{5120{,}1487.1500}{5120{,}1487 + 1500} = 1160{,}1285$$

Rd = 0,01 (Kern, tabel 12)

$$\frac{1}{Ud} = \frac{1}{Uc} + Rd = \frac{1}{1160{,}1285} + 0{,}01 = 0{,}01086$$

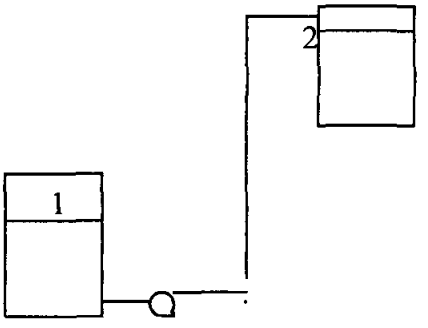
Ud = 92,0643

$$A = \frac{Q}{Ud.\Delta T} = \frac{5196393{,}583}{92{,}0643.50} = 1128{,}8618 \text{ ft}^2$$

Spesifikasi :

Bahan	: stainless steel
Kapasitas	: 340490,64 ft^3/jam
Diameter	: 2,6914 ft
Tinggi tanki total	: 5,5433 ft
Tinggi tutup atas	: 0,9383 ft
Tinggi tutup bawah	: 0,9383 ft
Tebal shell	: 1/4 in
Tebal tutup atas	: 1/4 in
Tebal tutup bawah	: 1/4 in
Jumlah	: 1 tanki

13. POMPA 3 (L-311)



Fungsi : mengalirkan HNO3 menuju tanki penampung

Rate = 1903,8903 kg/ jam = 4175,1980 lb/jam

Pada 1 atm dan 30°C :

Sg HNO3 = 1,504. m^3/kg (Perry 7ed, hal 2-214)

ρ HNO3 = (1,504/1).62,43 = 93,8947 lb/ft^3

ρ H2O = 995,6470 kg/m^3 = 62,1582 lb/ft^3 (Perry 7ed, hal 2-91)

$$\frac{1}{\rho_{\cdot laR..HNO3}} = \frac{0,6}{93,8947} + \frac{0,4}{62,1582} = 0,0128$$

ρ lar HNO3 60% = 1/0,0128 = 77,9707 lb/ft^3

volume = $\frac{4175,1980}{77,9707}$. = 53,5483 ft^3/jam = 0,0149 ft^3/s = 6,7037 gpm

μ HNO3 = 0,00138 lb/ft . s

Di_{opt} = 3,9 . $q_f^{0,45}$. $\rho^{0,13}$ (Peters & Timmerhaus, 4ed, p. 496)

= 3,9 .0,0149^{0,45} . 77,9707^{0,13} = 1,0350 in

Dipilih steel pipe (IPS) berukuran 1 in sch 40 :

ID = 1,049 in = 0,0874 ft

OD = 1,32 in

A = 0,864 in^2 = 0,006 ft^2 (Peters & Timmerhaus, 4ed, tabel 13, p. 888)

Kecepatan linear = $\frac{0,0149}{0,006}$ = 2,4833 ft/s

$$N_{Re} = \frac{\rho \cdot di \cdot v}{\mu} = \frac{77,9707\,lb/ft^3 \cdot 0,0874\,ft \cdot 2,4833\,ft/s}{0,00138\,lbm/ft \cdot s} = 12262,8938$$

$$\frac{1}{2 \cdot \alpha \cdot g_c} \cdot (v_2^2 - v_1^2) + \frac{g}{g_c} \cdot (Z_2 - Z_1) + \frac{P_2 - P_1}{\rho} + \Box F + W_s = 0$$

(pers 2.7-28 Geankoplis 3ed, p 275)

Dimana ΣF merupakan total fraksional losses, meliputi :

1. Losses karena kontraksi , hc
2. Losses karena friksi pada pipa lurus, Ft
3. Losses karena friksi pada elbow dan valve, Hf
4. Losses karena ekspansi pada bak penampung
5. Losses karena pressure drop.

Perhitungan ΣF :

1. Losses karena kontraksi , hc

$$Kc = 0,55 \text{ x } (1 - \frac{A_2}{A_1})$$

Dimana : A_1 = luas penampang tangki

A_2 = luas penampang pipa

Karena $A_1 >>> A_2$ maka (A_2/A_1) diabaikan

Kc = 0,55 x (1-0) = 0,55

$$hc = Kc \cdot \frac{v^2}{2 \cdot \alpha \cdot gc} = 0,55 \cdot \frac{2,.4833^2}{2 \cdot 1 \cdot 32,174} = 0,0527 \text{ ft.lbf/lbm}$$

2. Losses karena friksi pada pipa lurus, Ft

Digunakan pipa commersial steel ε = 0,00015 ft

ε/D = 0,00015/0,0874 = 0,00172

Dari fig 14-1 Peters and Timmerhaus 4ed diperoleh f = 0,009

Penafsiran panjang pipa lurus (ΔL) = 5 m = 16,4042 ft

$$Ft = 4f \cdot \frac{\Delta L}{D} \cdot \frac{v^2}{2 \cdot g_c}.$$

$$= 4.\ 0,009 \cdot \frac{16,4042\ ft}{0,0874} \cdot \frac{2,4833^2}{2 \cdot 32,174} = 0,6475$$

3. Losses karena friksi pada elbow dan valve, hf

Terdapat 2 elbow 90, 1 globe valve

Dari Geankoplis tabel 2.10-4 :

Kf = 2 . 0,75 + 1. 6 = 7,5

$$h = Kf \cdot \left(\frac{v^2}{2 \cdot \alpha \cdot g_c} \right)$$

$$= 7{,}5 \cdot \left(\frac{2{,}4833^2}{2 \cdot 1 \cdot 32{,}17} \right) = 0{,}7188 \ \frac{ft \cdot lbf}{lbm}$$

4. Losses karena ekspansi, pada inlet bak

Dimana : A_1 = luas penampang pipa

A_2 = luas penampang bak

Karena $A_1 <<< A_2$ maka A_1/A_2 diabaikan

$$K_{ex} = \left(1 - \frac{A_1}{A_2} \right)^2 = (1 - 0)^2 = 1$$

$$H_{ex} = K_{ex} \cdot \left(\frac{v^2}{2 \cdot \alpha \cdot g_c} \right) = 1 \cdot \left(\frac{2{,}4833^2}{2 \cdot 1 \cdot 32{,}17} \right) = 0{,}0958$$

5.Losses karena pressure drop di bak penampung

P_1 = 14,7 psia = 176,4 lbf/ft^2

P_2 = 14,7 psia = 176,4 lbf/ft^2

$\Delta P = 0$

$\Sigma F = 0{,}0527 + 0{,}6427 + 0{,}7188 + 0{,}0958 = 1{,}51$ ft lbf/lbm

$$W_s = \frac{1}{2 \cdot \alpha \cdot g_c} \cdot (v_2^2 - v_1^2) + \frac{g}{g_c} \cdot (Z_2 - Z_1) + \frac{P_2 - P_1}{\rho} + \Box F$$

$$W_s = \frac{1}{2.1.32{,}174} . 2{,}4833^2 + \frac{32{,}174 \ ft/lbf \cdot s^2}{32{,}174 \ ft/lbf \cdot s^2} \cdot 6 + 0 + 1{,}51$$

= 7,6058 ft.lbf/lbm

Efisiensi pompa (η) = 60% (Peters & Timmerhaus 4^{ed} fig 14-37, p.520)

$$\text{Brake hp} = \frac{-w_s \cdot m}{\eta \cdot 550}$$ (Geankoplis ed.3, pers.3.3-2)

$$\text{Bhp} = \frac{7{,}6058 \cdot 1{,}1157}{0{,}6 \cdot 550} = 0{,}0257 \text{ hp}$$

Efisiensi motor = 80% (Peters & Timmerhaus 4ed fig 14-38, p 521)

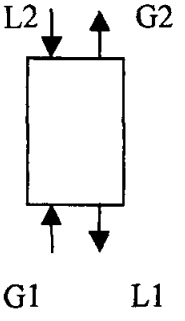
Sehingga dipakai pompa dengan motor = 0,0257/0,8 hp = 0,0321 hp

Spesifikasi

Tipe	: centrifugal pump
Rate aliran pompa	: 0,0169 ft^3/s
Power motor	: 0,0321 Hp
Bahan konstruksi	: stainless steel
Jumlah	: 1 buah

14. ABSORBER (D-240)

Fungsi : mengabsorbsi gas NO2 menjadi HNO3



Reaksi Overall :

$3NO_{2(g)}+H_2O_{(l)}$ -------- $2HNO_{3(08)}+NO_{(8)}$

Kondisi operasi

Suhu = 40 °C

Tekanan = 9,5 atm

Menghitung diameter kolom

Gas masuk kolom, G1

	Kmol/jam	kg/jam
NO =	1,4692	44,0764
NO_2 =	28,6299	1316,9767
N_2 =	414,6227	11609,4364
O_2 =	20,2845	649,1030
H_2O =	4,7210	84,9785
	469,7273 kmol/jam	13704,5710 kg/jam = 30212,899 lb/jam

Komponen	Fraksi mol	Fraksi berat
NO_2	0,0610	0,0961
N_2	0,8827	0,8471
O_2	0,0432	0,0474
H_2O	0,0101	0,0062
NO	0,0031	0,0032

Gas keluar kolom, G2

	Kmol/jam	kg/jam
NO_2 =	1,4315	65,8488
N_2 =	414,6227	11609,4364
O_2 =	20,2845	649,1030
NO =	10,5354	316,0608
	446,8741 kmol/jam	12640,449 kg/jam= 27866,9511 lb/jam

Komponen	Fraksi mol	Fraksi berat
NO_2	0,0032	0,0052
N_2	0,9278	0,9184
O_2	0,0454	0,0514
NO	0,0236	0,0251

Laju alir liquid masuk kolom (L_2) = 839,7682 kg/jam = 1851,3408 lb/jam

Liquid keluar kolom,L1

HNO3 = 18,1323 kmol/jam = 1142,3342 kg/jam

H2O = 42,3087 kmol/jam = 761,5561 kg/jam

60,4410 kmol/jam 1903,8903 kg/jam = 4197,2890 lb/jam

Komponen	Fraksi mol	Fraksi berat
HNO3	0,3	0,6
H2O	0,7	0,4

Direncanakan *Packed Column* dengan memakai packing 1" keramik Rasching Ring (RR).

Dari.Treyball, table 6.3 didapat.

C_f = 155

Wall thickness = 3mm

C_D = 301 $a_p = 190 m^2/m^3 = 58 ft^2/ft^3$

gc = $4,18.10^8$

Menghitung diameter bagian Atas kolom

G_2 keluar pada suhu 40°C. L_2 masuk pada suhu 40°C.

G_2 = 27866,449 lb/jam

L_2 = 1851,3408 lb/jam

BM G_2 = (0,0032.46)+(0,0236.30)+(0,0454.32)+(0,9277.28)=28,28lb/lbmol

ρG_2 pada 3,38 atm dan 40°C (104°F),

$$G_2 = \frac{28,28}{359}.\frac{460+32}{460+86}.\frac{9,37}{1} = 0,6651 \text{ lb/ft}^3$$

ρL_2 pada 30°C, ρ_L= 0,993g/mol= 61,99lb/ft^3 (Perry 6^{th}ed, table 3-28).

μL_2 = 0,73 cp = 1,77 lb/jam (Kern, fig 14)

$$\frac{L_2}{G_2}\left(\frac{\rho_G}{\rho_L-\rho_G}\right)^{\frac{1}{2}} = \frac{1851,3408}{27866,449}\left(\frac{0,6651}{61,991-0,6651}\right)^{\frac{1}{2}} = 0,0069$$

Dari. Treyball, fig 6.34

$$\frac{G_f^{\,2}.C_f.\mu_L.^{0,1}.J}{gc.\rho_G.(\rho_L-\rho_G)}=0,375$$

dimana G_f = rate massa pada kondisi flooding lb/jam.ft^2

$$\frac{G_f^{\,2}.(155)(0,73)^{0,1}.1,502}{(4,18.10^8)(0,6651)(61,99-0,6651)}=0,375$$

G_f = 5280,3728lb/jam.ft$_2$

$G_{operasi}$ = 40-70% G_f

Diambil : $G_{operasi}$ = 50%. G_f = (0,5.5280,3728)=2640,1864lb/jam.ft^2

Luas Penampang Kolom

$$A=\frac{G_2}{G_{operasi}}=\frac{27866,449}{2640,1864}=10,5559\,ft$$

Diameter Kolom

$$A=1/4\,\eta D^2 \rightarrow 10,5559=1/4\,\eta D^2$$

D = 4,1667ft. ≈ 4,5ft

Rasching Ring = $\frac{D_t}{30}=\frac{4,5.12}{30}=1,8"$

Jadi diameter kolom bagian atas = 4,5ft

Menghitung diameter bagian bawah kolom

G_1 = 30212,899 lb/jam

L_1 = 4197,2890 lb/jam

BM G_1 = (0,0904.46)+(0,7983.28)+(0,0447.32)+(0,0056.18)+(0,0031.30)

= 28,135lb/lbmol .

$$\rho G=\frac{28,155}{359}.\frac{460+32}{460+86}.\frac{9,37}{1}=0,6617 lb/ft^3$$

ρL = 0,9922 g/ml = 61,94lb/ft^3 (Perry 6ed, table 3-28 & 3-66)

ρHNO_3= 1,3398 g/ml = 83,64lb/ft^3

$$\rho_L=\frac{1}{\frac{x_1}{\rho_1}+\frac{x_2}{\rho_2}}=\frac{1}{\frac{0,303}{61,94}+\frac{0,697}{83,64}}=75,613 lb/ft^3$$

μ_{L1} pada 30°C (μ_L)

μ_{H2O} = 0,657 cp = 1,5899 lb/jam.ft (Kern, figure 14)

μ_{HNO3} = 1,7 cp = 4,114 lb/jam.ft

$\mu_L = (x_1 . \mu_L^{1/3} + x_2 . \mu_L^{1/3}) = (0,3 . 4,114^{1/3}) + (0,7 . 1,5899^{1/3})$

= 1,314 lb/jam.ft

untuk :

$$\frac{L_1}{G_1}\left(\frac{\rho_G}{\rho_L - \rho_G}\right)^{\frac{1}{2}} = \frac{4197,2890}{30212,899}\left(\frac{0,6617}{75,613 - 0,6617}\right)^{\frac{1}{2}} = 0,0123$$

dari figure 6.34, Treyball

$$\frac{G_f^{\,2} . c_f . \mu_L^{\,0,1} . j.}{gc . \rho_G . (\rho_L - \rho_G)} = 0,25$$

$$\frac{G_f^{\,2} . 155 . 1,314^{0,1} . 1,502.}{4,18 . 10^8 . 0,6617 . (75,613 - 0,6617)} = 0,25$$

G_f = 4654,2286 lb/ft^2.jam

$G_{operasi}$ = 40 – 70 % (Perry 3ed, hal 674)

Diambil $G_{operasi}$ = 50 % G_f = 0,5. 4654,2286 = 2327,1143 lb/ft^{2}jam

Luas penampang kolom

$A = G_1/G_{operasi}$ = 30212,899 / 2347,1143 = 13,7774 ft^2

Diameter kolom

$A = 0,25 . 3,14 . D^2$

$13,7774 = 0,25 . 3,14 . D^2$

D = 4,1894 ft = 4,5 ft

Rashing ring = D.t/30 = 4,5. 12/30 = 1,8"

Jadi diameter kolom bagian bawah = 4,5 ft

Menghitung tinggi kolom packing

Koefisien perpindahan massa fase liquida

$K_L.a = D_{AB} . \alpha . (L/\mu_L)^{1-n} . (\mu_L/\rho . D_{AB})^{0,5}$

Untuk rasching ring (RR) 1" harga $\alpha = 100$; n = 0,22

$$D_{AB} = 1{,}173.10^{-16} (\varphi.M_B)^{1/2}.\frac{T}{\mu_L.\vartheta_A^{0,6}}$$

Dimana : $k_L.a$ = koefisien perpindahan massa fase liquida, jam^{-1}

L = rate air, $ft^3/ft^2.jam$

μ_L = viskositas air, lb/ft.jam

D_{AB} = difusivitas gas NO_2 dalam air, ft^2/jam

ϑ_A = volum molar solute NO_2 pada titik didih

ρ = densitas air, lb/ft^3

M_B = berat molekul air lb/lbmol

T = suhu operasi, K

φ = association parameter dari air = 2,6

ϑ_A = 0,0156 + 2 (0,0074) = 0,0304 m3/kmol

(Geankoplis, table 6.3-2)

$$D_{AB} = 1{,}173.10^{-16} (2{,}6.18)^{1/2}.\frac{30+273}{7{,}3.10^{-4}.0{,}0304^{0,6}}$$

$= 2{,}8.10^{-9}\ m^2/s = 1{,}08.10^{-4}\ ft^2/jam$

Rate air = 1857,3646 lb/jam

Luas penampang kolom (A) = 0,25. □. $4{,}5^2 = 15{,}8963\ ft^2$

Rate volumetric air = 1857,3646/61,99 = $29{,}9623\ ft^3/jam$

L = 29,9623/15,8963 = $1{,}8849\ ft^3/ft^2.jam$

$K_L.a = 1{,}08.10^{-4}.100.(1{,}8849/1{,}77)^{1-0,22}.(\ 1{,}77/61{,}99.1{,}08.10^{-4})^{0,5}$

$= 0{,}1844\ jam^{-1}$

Koefisien perpindahan massa fase gas

Untuk RR 1" berlaku :

$$K_G.\frac{P_f}{G} = \frac{1{,}07}{M}\left(\frac{\sqrt{Ap}}{d}\right)^{-0,41}\left(\frac{G.d}{\mu_G}\right)^{-0,41}\left(\frac{\mu_G}{\rho_G.D_G}\right)^{-\frac{2}{3}}$$

Dimana : KG = koefisien perpindahan massa fase gas, lb/ft2.jam.atm

G = rate gas, lb/ft2.jam

Pf = rata-rata logaritmik tekanan parsial gas inert, atm

M = berta molekul gas, lb/lbmol

μ_G = viskositas gas, lb/ft.jam

ρ_G = densitas gas, lb/ft3

d = 1 in = 0,0833 ft

Dari figure 15, Kern :

μ_{NO2} = 0,019 cp

μ_{NO} = 0,016 cp

μ_{N2} = 0,018 cp

μ_{O2} = 0,021 cp

μ_{H2O} = 0,01 cp

$\mu_{campuran}$ = (0,019. 0,0904) + (0,016. 0,0031) + (0,018. 0,7983)
+ (0,021. 0,0447) + (0,01. 0,0056)
= 0,02 cp = 0,048 lb/ft.jam

$$G = \frac{30212,899}{15,8963} = 2016,9281 \text{ lb/ft2.jam}$$

$$D_{AB} = \frac{1.10^{-7}.T^{1,75}.(1/M_A + 1/M_B)^{1/2}}{P((\Sigma \vartheta_A)^{1/3} + (\Sigma \vartheta_B)^{1/3})^2}$$

Dimana : DAB = difusivitas gas A dan B, m2/s

T = suhu operasi, K

M = berat molekul, kg/kmol

ϑ = volum difussion

Untuk $NO_2 - H_2O$

$M_A = 46$ $\vartheta_A = 16,65$

$M_B = 18$ $\vartheta_B = 12,7$

$$D_{AB} = \frac{1.10^{-7}.313^{1,75}.(1/46 + 1/18)^{1/2}}{9,37((\Sigma 16,65)^{1/3} + (\Sigma 12,7)^{1/3})^2} = 2,893.10^{-6} \text{ m}^2/\text{s}$$

Pada bagian bawah kolom

Fraksi mol gas inert = 0,9133

Tekanan parsial gas inert = 0,9133. 9,37 = 8,5576 atm

Pada bagian atas kolom

Fraksi mol gas inert = 0,9967

Tekanan parsial gas inert = 0,9967. 9,37 = 9,339 atm

$$Pf = \frac{9,339 - 8,5576}{\ln \frac{9,339}{8,5576}} = 8,9426 \text{ atm}$$

$$K_G.\frac{8,9426}{2016,9281} = \frac{1,07}{28,135}(2,5)^{-0,41}\left(\frac{2016,9281.0,0833}{0,048}\right)^{-0,41}\left(\frac{0,048}{0,6619.2,893.10^{-6}}\right)^{-\frac{2}{3}}$$

$K_G = 0,1178$ lb/ft^2.jam.atm

$a = 1,8$ cm^{-1} = 54,865 ft^{-1}

$K_G.a = 0,1178.54,865 = 6,4620$ lb/ft3.jam.atm

Bagian bawah kolom

Tekanan parsial gas $NO_2 = 0,0598.\ 9,37 = 0,5603$ atm

$K_G.a\ .P_A = 6,4620\ .0,5603 = 3,6208$ lb/jam.ft^2

Rate massa :

$HNO_3 = 2518,3735$ lb/jam = 39,9243 lbmol/jam

H_2O = 1678,9156 lb/jam

$\rho_{campuran} = 75,5613$ lb/ft^3

$$V_{campuran} = \frac{2518,3735 + 1678,9156}{75,613} = 55,4408 \text{ ft}^3\text{/jam}$$

Konsentrasi HNO_3 (C_B) = 39,9243/55,4408 = 0,7201 lbmol/ft^3

$K_L.a.C_B = 0,1844.0,7201 = 0,1328$ lbmol/ft3.jam = 8,3655 lb/ft^3.jam

$K_L.a.C_B > K_G.a.P_A$

Bagian atas kolom

Tekanan parsial gas $NO_2 = 0,0032.9,37 = 0,02998$ atm

$K_G.a.P_A = 6,4620.\ 0,02998 = 0,1938$ lb/ft3.jam

Rate massa

H_2O = 1857,3646 lb/jam = 103,1869 lbmol/jam

ρ_{H2O} = 61,99 lb/ft^3

$$V_{campuran} = \frac{1851,3408}{61,99} = 29,9623 \text{ ft}^3\text{/jam}$$

Konsentrasi HNO_3 (C_B) = 103,1869/29,9623 = 3,4439 lbmol/ft^3

$K_L.a.C_B$ = 0,1844.3,4439 = 0,6351 lbmol/ft^3.jam = 11,4310 lb/ft^3.jam

$K_L.a.C_B > K_G.a.P_A$

Karena $K_L.a.C_B > K_G.a.P_A$ baik pada bagian atas maupun bawah maka yang mengontrol adalah tahanan fase liquid

Untuk menghitung tinggi kolom packing:

$$H = \left(\frac{G}{K_L.a.C_B}\right)\ln\frac{Y_T}{Y_B}$$

Dimana : H = tinggi kolom packing, ft

G = rate massa liquid, lb/ft^2.jam

$K_L.a$ = koefisien perpindahan massa fase gas lb/jam.ft3.atm

C_B = konsentrasi, lb/ft^3

Y_B = fraksi mol H2O pada bagian bawah kolom

Y_T = fraksi mol H2O pada bagian atas kolom

$$H = \left(\frac{2016,9218}{9,8186}\right)\ln\frac{1}{0,7} = 73,2574 \text{ ft}$$

Menghitung presure drop

L2 = 116,8429 lb/ft2.jam

G1 = 2016,9345 lb/ft2.jam

$$\rho_G = \frac{28,155}{359}.\frac{460+32}{460+86}.\frac{9,37}{1} = 0,6617 lb/ft^3$$

ρ_L= 0,993 g/mol = 61,99lb/ft^3 (Perry 6thed, table 3-28).

$$\frac{\Delta P}{z} = m.(10^{-8}).(10^{n.L2/\rho L}).\frac{G_1^2}{\rho_G}$$

untuk rasching ring 1" m = 32,1 ; n = 0,00434 (Perry 6ed, hal 18-24)

$$\frac{\Delta P}{z} = 32{,}1.(10^{-8}).(10^{0{,}00434.116{,}8429/61{,}99}).\frac{2016{,}9345^2}{0{,}6671}$$

$= 1{,}9947$ lb/ft^2.ft $< 2{,}6$ lb/ft^2.ft (memenuhi syarat)

Menghitung tebal kolom

Menggunakan bahan konstruksi carbon steel SA-283 grade C

P operasi = 9,37 atm = 137,739 psi =152,439 psig

P design = 1,2 . 152,439 = 182,9268 psig

Dari tabel 13.1, Brownel & Young :

F allowable = 18750 lb/in^2

$\varepsilon = 85\%$

$$ts = \frac{P..ri}{f.\varepsilon - 0{,}6.P}$$ (Brownel & Young, pers 13.1)

$$= \frac{165{,}2868.\frac{54}{2}}{18750..0{,}85 - .0{,}6.165{,}2868}$$

$$= 0{,}2818 = \frac{3}{8} \text{ in}$$

Menghitung Tebal Head

Direncanakan :

- bahan konstruksi stainless steel SS
- bentuk head eliptical dished head

Harga k = 2 (Brownel & Young, hal 133)

$V = 1/6\ (2 + k^2)$

$= 1/6\ (2 + 2^2) = 1$

$$th = \frac{P..d..v}{2f.\varepsilon - 0{,}2.P}$$

$$= \frac{165{,}2868..54}{2..18750.0{,}85 - 0{,}2..165{,}2868}$$

$$= 0{,}2803 = \frac{3}{8} \text{ in}$$

Menghitung tinggi head

dari table 5.11 Brownell & Young,

sf = 3 in

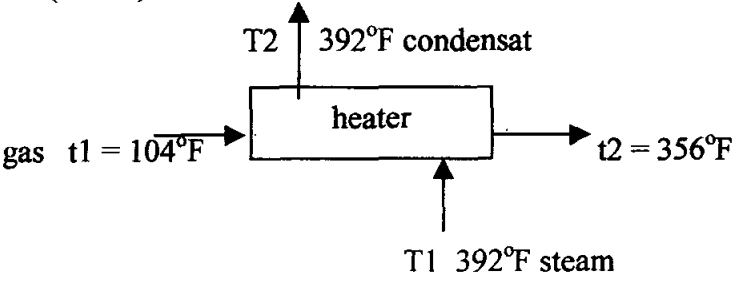
tinggi head =(ID/4) + sf + t

= 3 + 0,2803 + (54 / 4) = 16,7803 in = 1,3984 ft

Spesifikasi :

Bahan	: stainless steel
Diameter	: 4,5 ft
Tinggi tanki total	: 76,0542 ft
Tinggi tutup atas	: 1,3984 ft
Tinggi tutup bawah	: 1,3984 ft
Tebal shell	: 3/8 in
Tebal tutup atas	: 3/8 in
Tebal tutup bawah	: 3/8 in
Jumlah	: 1 tanki

15. HEATER (E-233)



Fungsi : untuk memanaskan gas recycle dari abosrber

Tipe : shell and tube

Perhitungan :

Neraca Panas

m gas = 6320,2245 kg/jam = 13933,4755 lb/jam

M steam = 273,7055 kg/jam = 603,4071 lb/jam

Q = 531193,8592 kkal/jam =2107912,14 btu/jam

$$LTMD = \frac{(392-104)-(392-356)}{\ln\frac{(392-104)}{(392-356)}} = 121,1864^{o}F$$

$\Delta t = 121,1864\ ^{o}F$

$Tc = 392^{o}F$

$tc = (104+356)/2 = 230^{o}F$

Trial $U_D = 10$

$$A = \frac{Q}{U_d.\Delta T} = \frac{2107912,14}{10.121,1864} = 378,9163$$

Ditetapkan:

$OD_{tube} = 1$ in, 10 BWG (Kern, table 10)

$ID_{tube} = 0,732$ in

L = 12 ft

a" = 0,2618 ft^2

$$\text{Jumlah tube} = \frac{A}{a"..L} = \frac{378,9163}{0,2618..12} = 120,6125$$

Dari tabel 9 Kern, untuk square pitch

$P_T = 1\frac{1}{4}$ in

Nt standar = 122 buah

Passes = 6

$ID_{shell} = 19,25$ in

$$U_D \text{ terkoreksi} = \frac{120,6125}{122}10 = 9,7725$$

Shell, steam	Tube, gas
$C' = P_T - OD = 1\frac{1}{4} - 1 = \frac{1}{4}$	a't = 0,421 (tabel 10)
$B = \frac{3}{4}.19,25 = 14,4375$	$at = \frac{Nt..a't}{144..n} = \frac{122x0,421}{144x6} = 0,0594\ ft^2$

$$a_s = \frac{ID..c'.B}{144.P_T} = \frac{19,25.\frac{1}{4}.14,4375}{144.1\frac{1}{4}}$$

$= 0,3860 \text{ ft}^2$

$$Gs = \frac{W}{as} = \frac{603,4071}{0,3860}$$

$= 2848,5106$ lb/jam ft

Pada Tc = 392°F

$\mu = 0,0165.\ 2,42 = 0,0399$ lb/jam ft (fig. 15)

De = 0,72/12 = 0,06 (fig. 28)

c = 0,49 (fig. 3)

k = 0,0187 (tab. 5)

$$Res = \frac{D.Gt}{\mu} = \frac{0,06.2848,5106}{0,029}$$

$= 4283,4746$

jH = 35 (fig. 28)

$$\left(\frac{c.\mu}{k}\right)^{\frac{1}{3}} = \left(\frac{0,49.0,0399}{0,0187}\right)^{\frac{1}{3}} = 1,0149$$

$$\frac{ho}{\phi s} = jH\left(\frac{k}{Ds}\right)\left(\frac{c.\mu}{k}\right)^{\frac{1}{3}}$$

$$= 35\frac{0,0187}{0,06}1,0149 = 11,0709$$

$$Gt = \frac{w}{at} = \frac{13933,4775}{0,0594}$$

$= 234592,9798$ lb/jam ft

Pada tc = 230°F

$\mu = 0,034\ .\ 2,42 = 0,0823$ lb/jam ft (fig. 14)

c = 0,2878 (fig. 2)

k = 0,0369 (tab. 4)

D = 0,732/12 = 0,061 ft (tab.10)

$$Ret = \frac{D.Gt}{\mu} = \frac{0,061.234592,9798}{0,0,0823}$$

$= 173878,1503$

$$\frac{L}{D} = \frac{12}{0,061} = 196,7213$$

jH = 400 (fig. 24)

$$\left(\frac{c.\mu}{k}\right)^{\frac{1}{3}} = \left(\frac{0,2878.0,0823}{0,0369}\right)^{\frac{1}{3}} = 0,8626$$

$$\frac{hi}{\phi t} = jH\left(\frac{k}{D}\right)\left(\frac{c.\mu}{k}\right)^{\frac{1}{3}}$$

$$= 400\left(\frac{0,0369}{0,061}\right)0,8626$$

$= 208,7209$

$$\frac{hio}{\phi t} = \frac{hi}{\phi t}.\frac{ID}{OD} = 208,7209.\frac{0,732}{1}$$

$= 152,7837$

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

$$= 230 + \frac{11,0709}{152,7837 + 11,0709}(392-230)$$

$$= 240,95^{\circ}F$$

Pada tw = 240,95°F

$\mu_w = 0,018.x\ 2,42 = 0,0436$ (fig.15)

$$\phi s = \left(\frac{\mu}{\mu w}\right)^{0,14} = \left(\frac{0,0399}{0,0436}\right)^{0,14} = 0,9877$$

ho = 11,0709 x 0,9877 = 10,9347

pada tw = 240,95°F

$\mu_w = 0,035.x\ 2,42 = 0,0847$ (fig.14)

$$\phi t = \left(\frac{\mu}{\mu w}\right)^{0,14} = \left(\frac{0,0823}{0,0847}\right)^{0,14} = 0,996$$

hio = 152,7837 x 0,996 = 152,1726

$$U_C = \frac{hio..ho}{hio + ho} = \frac{10,9347..152,1726}{10,9347 + 152,1726} = 10,2016$$

$$Rd = \frac{Uc - U_D}{Uc..U_D} = \frac{10,2016 - 9,7725}{10,2016.9,7725} = 0,0043$$ (memenuhi > 0,003)

Perhitungan pressure drop

Shell, steam

Nres = 4283,4746

f = 0,0017 (fig. 29)

$$N+1 = \frac{L}{B}.12 = \frac{12}{7,5}.12 = 19,2$$

ρ steam = 0,0592 lb/ft^3

(Geankoplis, Tabel A-3.3)

$$s = \frac{0,0592}{62,5} = 0,00095$$

Tube, gas

Nret = 173878,1503

f = 0,00013 (fig. 26)

BM gas = 28,28 kg/kmol

$$\rho \text{ gas} = \frac{P.BM}{R.T} = \frac{9,37.28,28}{0,0821.503}$$

= 6,4166 kg/m^3 = 0,4010 lb/ft^3

IDs = 10 in =0,8333 ft

$$\Delta Ps = \frac{f.Gs^2.IDs.(N+1)}{5{,}22.10^{10}.De.s.\phi s}$$

$$= \frac{0{,}0028(2848{,}5106)^2.1{,}6042.9{,}974}{5{,}22.10^{10}.0{,}06.0{,}00095.0{,}9987}$$

= 1,1223 psi

(memenuhi < 10 psi)

s = 0,4010/62,5 = 0,0064

$$\Delta Pt = \frac{f.Gt^2.L.n}{5{,}22.10^{10}.D.s.\phi t}$$

$$= \frac{0{,}00013(234592{,}9798)^2.12.6}{5{,}22.10^{10}.0{,}061.0{,}0064.0{,}996}$$

=0,2538 psi

$$\frac{v}{2g'} = 0{,}007 \qquad \text{(fig. 27)}$$

$$\Delta Pr = \frac{4n}{s}\frac{v}{2g'}$$

$$= \frac{4.6}{0{,}0064} 0{,}007 = 1{,}625 \text{ psi}$$

$$\Delta P_T = 0{,}2538 + 1{,}625 = 1{,}8788 \text{ psi}$$

(memenuhi < 2 psi)

Spesifikasi:

Tipe : shell & tube

Shell : ID = 19,25 in; baffle space = 14,4375 in; passes = 1

Tube : OD = 1 in; 10 BWG; L = 12 ft; passes = 6; $P_T = 1\frac{1}{4}$ in (square pitch)

Jumlah tube : 122

Ud = 9,7725

Uc = 10,1026

Rd = 0,0043

ΔP shell = 1,8788 psi

ΔP tube = 1,1223 psi

16. EKSPANDER (G-250)

Fungsi : untuk memperkecil tekanan gas buang

P input = 9,5 atm = 9,5 bar

P output = 1 atm = 1 bar

Massa = 6320,8357 kg/jam = 1,7558 kg/s

Asumsi effisiensi = 55%

$$\rho \text{ gas} = \frac{P.BM}{R.T} = \frac{9,5.28,28}{0,0821.303} = 10,7998 \text{ kg/m}^3$$

$$Ws = \frac{\varepsilon.m.(p1 - p2)}{\rho} \quad \text{(Ulrich hal.93 pers.4-19)}$$

$$= \frac{0,55..1,7558..(9,5 - 1).10^5}{10,7998} = 76004,7871 \text{ J/s} = 76,027 \text{ Kw}$$

Spesifikasi :

Tekanan masuk	: 9,5 bar
Tekanan keluar	: 1 bar
Rate gas	: 1,7558 kg/s
Ws	: 76,027 Kw
Jumlah	: 1 buah

APPENDIX D

PERHITUNGAN ANALISA EKONOMI

Harga alat akan berubah setiap saat tergantung pada kondisi ekonomi dan politik, untuk itu dibutuhkan suatu metode yang dapat dipakai untuk mengkonversi harga alat pada beberapa tahun yang lalu agar dapat diperoleh harga alat yang ekivalen pada saat ini.

Ekivalensi itu dapat dihitung dengan menggunakan persamaan :

$$\text{Harga alat tahun ini} = \frac{\textit{indeks harga saat ini}}{\textit{indeks harga tahun A}} \text{ x harga alat tahun A}$$

Harga alat pada tahun A diperoleh dari literatur Peters & Timmerhaus.

Sedangkan indeks harga tersebut adalah :

Chemical Engineering Plant cost index

- Tahun A (Januari 1990) = 356 (tabel 3, hal 163, Peters & Timmerhaus)
- Saat ini (Januari 2002) = 394,3 (Chemical Engineering, Januari 2002)

D.1. Perhitungan Harga Peralatan

Contoh perhitungan :

Tanki penampung NH_3 (F-110)

Kapasitas = 2617,9574 ft^3 = 19582,3214 gal

Harga Januari 1990 = $ 220.000 (fig 14-56, hal 539, Peters & Timerhaus)

$$\text{Harga alat saat ini} = \frac{394,3}{356} x220000 = \$\ 243.668,54$$

Dengan cara yang sama didapatkan harga alat yang lain seperti pada tabel I.1.1.

Tabel D.1.1 Harga Peralatan Proses

No.	Nama alat	Kode	Jumlah	Harga, $
1	Tangki penampung NH_3	F-110	2	243.668,54
2	Filter udara	H-120	1	5.537,92
3	Kompresor	G-121	1	360.265.63
4	Kompresor	G-122	1	360.265.63
5	Furnace	Q-211	1	521.516,85
6	Oksidator 1	R-210	1	632.275,28
7	Gas-gas heat exchanger	E-214	1	8.306,88
8	Bag filter	H-220	1	44.366,85
9	Blower 2	G-231	1	88.606,74
10	Oksidator 2	E-230	1	295.756.42
11	Condensor	E-232	1	9.968,26
12	Blower 3	G-241	1	7.753,09
13	Absorber	D-240	4	949.111,72
14	Heater	E-233	1	11.075,84
15	Pompa 3	L-311	1	1.107,58
16	Tanki penampung HNO3	F-310	1	232.592,70
17	Ekspander	G-250	1	160.265,63
	Total harga alat			3.935.441,56

Tabel D.1.2. Harga Peralatan Utilitas

No.	Nama Alat	Kode	Jumlah	Harga, $
1	Tangki sand filter	H – 355	2	10.522,56
2	Tangki demineralisasi	D – 366	2	42.088,20
3	Tangki koagulator dan flokulator	H – 353	1	26.718,75
4	Pompa air sumur	L – 350	1	1.100,00
5	Pompa air ke bak koagulator	L – 352	1	1.100,00
6	Pompa	L – 358	1	1.700,00
7	Pompa air ke bak pendingin	L – 364	1	1.250,00
9	Pompa air pendingin	L – 366	1	1.200,00
10	Pompa air proses	L – 360	1	1.200,00
11	Pompa air sanitasi	L – 362	1	1.000,00
8	Cooling tower	E – 363	1	16.440,70
9	Generator		1	41.200,57
10	Boiler		1	15.482,81
	Total harga alat			161.003,59

Tabel D.1.3. Bak Utilitas

No.	Nama Peralatan	Kode	Jumlah	Luas, m^2
1	Bak air sumur	F – 351	1	87,12
2	Bak pengendapan	H – 353	1	93,80
3	Bak air bersih	F – 357	1	47,00
4	Bak umpan air boiler	F – 367	1	9,35
5	Bak air pendingin	F – 365	1	167,9
6	Bak air proses	F – 359	1	11,16
7	Bak air sanitasi	F – 361	1	11,88
	Total			428,21

Harga bak = Rp. 250.000,-/m^2

Total harga bak utilitas = (Rp. 250.000,- / m^2) * 428,21 m^2 = Rp. 107.052.500,-

Total harga peralatan = $ 3.935.441,56+ $ 161.003,59+ Rp. 107.052.500,-

= ($ 4.096.445,15 x Rp. 9500,-/$) + Rp. 107.052.500,-

= Rp. 39.023.281.430,-

D.2. Perhitungan Harga Tanah dan Bangunan

Luas tanah = 10.000 m^2

Harga tanah = Rp. 500.000 / m^2

Harga total tanah = 10.000 x Rp. 500.000 = Rp. 5.000.000.000,-

Luas bangunan kantor = 350 m^2

Harga bangunan = Rp.1.000.000,-

Harga total bangunan = Rp. 350.000.000,-

Luas bangunan lain – lain = 3254 m^2

Harga bangunan = Rp. 500.000,-

Harga total bangunan lain – lain = Rp. 1.627.000.000,-

Luas Pabrik dan gudang = 950 m^2

Harga bangunan pabrik = Rp. 800.000,-

Harga total bangunan pabrik = Rp. 760.000.000,-

Harga total tanah dan bangunan = Rp. 5.000.000.000 + Rp. 350.000.000 +
Rp. 1.627.000.000 + Rp. 760.000.000
= Rp. 7.737.000.000,-

D.3. Perhitungan Harga Bahan Baku dan Produk

1. Harga Bahan baku
   - NH_3

     Harga = Rp. 1.750,- / kg

     Kebutuhan = 32.174,5260 kg / hari

     Total = Rp. 56.305.420 / hari = Rp. 18.580788.770.,- / tahun
   - Katalis Pt

     Harga = Rp. 50.000.000,- / kg

     Kebutuhan = 0,1130 kg / 14 hari

     Total = Rp. 5.650.000 / 14 hari = Rp. 133.178.572,- / tahun

Total harga bahan baku per tahun = Rp. 18.580.788.770 + Rp. 133.178.572
= Rp. 18.713.967.340,-

2. Harga jual

- HNO_3

  Harga = Rp. 10.000,- / kg

  Produksi = 1901,5133 kg / jam = 45.636,3192 kg / hari

  Total = Rp.456.363.192,- / hari

  = Rp. 150.599.853.400,- / tahun

D.4. Perhitungan Gaji Karyawan

No	Jabatan	Jumlah	Upah./bulan, Rp	Total, Rp
1	Direktur Utama	1	10.000.000	10.000.000
2	Direktur Teknik dan Produksi	1	6.000.000	6.000.000
3	Direktur Administrasi & Keuangan	1	6.000.000	6.000.000
4	Sekretaris	3	1.500.000	4.500.000
5	Kabag Produksi	1	4.000.000	4.000.000
6	Kabag Teknik	1	4.000.000	4.000.000
7	Kabag Umum	1	4.000.000	4.000.000
8	Kabag Pemasaran	1	4.000.000	4.000.000
9	Kabag Administrasi & Keuangan	1	4.000.000	4.000.000
10	Kasie Proses	1	2.500.000	2.500.000
11	Kasie Utilitas	1	2.500.000	2.500.000
12	Kasi Laboratorium	1	2.500.000	2.500.000
13	Kasi Maintenance	1	2.500.000	2.500.000

14	Kasi Personalia	1	2.500.000	2.500.000
15	Kasi Keamanan	1	2.500.000	2.500.000
16	Kasi Pemasaran	1	2.500.000	2.500.000
17	Kasi Gudang	1	2.500.000	2.500.000
18	Kasi Keuangan	1	2.500.000	2.500.000
19	Karyawan Proses	36	800.000	28.800.000
20	Karyawan Utilitas	9	800.000	7.200.000
21	Karyawan Laboratorium	6	800.000	4.800.000
22	Karyawan Maintenance	9	800.000	7.200.000
23	Karyawan Personalia	4	800.000	3.200.000
24	Karyawan Keamanan	12	600.000	7.200.000
25	Karyawan Pemasaran	5	800.000	4.000.000
26	Karyawan Gudang	9	750.000	6.750.000
27	Karyawan Keuangan	3	800.000	2.400.000
28	Karyawan Litbang	1	800.000	800.000
29	Sopir	4	600.000	2.400.000
30	Tukang kebun	2	500.000	1.000.000
	Total =	120		144.750.000

Gaji karyawan per bulan = Rp. 144.750.000,-

Ditetapkan satu tahun produksi adalah 12 bulan ditambah 1 bulan tunjangan untuk hari raya. Jadi gaji karyawan per tahun adalah = Rp. 144.750.000 * 13 bulan

= Rp. 1.881.750.000,-

D.5. Perhitungan Biaya Utilitas

1. Kebutuhan Air

   Air yang harus disuplai per hari = 442,7916 m^3

   Harga pengolahan Air Sumur = Rp. 300,-

   Biaya air per tahun = (442,7916 m^3 / hari * Rp.300,- / m^3) x 330 hari/tahun

   = Rp. 43.836.368,4,-

2. Kebutuhan Alum

   Kebutuhan alum per hari = $1{,}1148\ kg * \frac{60\ menit}{jam} * \frac{1}{25\ menit} * 24\ jam$

   = 64,2125 kg

   Harga alum = Rp. 3000 / kg

   Biaya alum per tahun = Rp. 3000 * 64,2125 * 330

   = Rp. 63.570.356,-

3. Kebutuhan Listrik

   Kebutuhan listrik total = 1831,1374 KW

   Beban listrik terpasang = 1,2 * 1831,1374 KW = 2197,3649

   Biaya beban per bulan = Rp. 25.000,-

   Biaya beban per tahun = 12 bulan * Rp. 25.000,- / bulan * 2197,3649

   = Rp. 659.209.470,-

   Biaya listrik : WBP = Rp. 455,- / KW (pk. 18.00 – 22.00)

   LWBP = Rp. 350,- / KW (pk. 22.00 – 18.00)

Biaya listrik terpakai per tahun :

= [((4 jam * 2197,3649 KW * Rp. 455,- / KW) + (20 jam * 2197,3649 KW * Rp. 350,- / KW)) * 330 hari / tahun] + [((4 jam * 15,73 KW * Rp.455,- / KW + (20 jam * 15,73 KW * Rp.350,- / KW)) * 365 hari / tahun]

= Rp. 5.129.453.030,-

Biaya listrik total per tahun = biaya beban + biaya listrik terpakai

= Rp. 659.209.470,- + Rp. 5.129.453.030,-

= Rp. 5.788.662.500,-

4. Kebutuhan bahan bakar

Kebutuhan bahan bakar IDO per bulan = 50467 lt

Harga bahan bakar per liter = Rp. 1.133,-

Biaya bahan bakar per tahun = 50467 lt / bln * 12 bln / th x Rp.1.133

= Rp. 686.500.035,-

Harga solar per liter = Rp. 1.860,-

Kebutuhan solar per bulan = 3473,63 lt

Biaya bahan bakar per tahun = 3473,63 lt / bln * 12 bln / th x Rp.1.860

= Rp. 77.531.421,-

Total biaya bahan bakar per tahun = 77.531.421 + 686.500.035

= Rp. 764.031.456,-

Kebutuhan bahan bakar LNG per bulan = 292.804,56 kg = 645.512,69 lb

= 187.269,6181 gal

= 708.817,631 lt

Harga bahan bakar per liter = Rp. 500,-

Biaya bahan bakar per tahun = 708.817,631 lt / bln * 12 bln / th x Rp.500,-

= Rp. 4.252.905.786,-

Biaya total bahan bakar = Rp. 764.031.456 + Rp. 4.252.905.786

= Rp. 5.016.937.242,-

Total biaya utilitas per tahun :

= Rp. 63.570.356 + Rp. 12.282.100.970 + Rp. 5.016.937.242

= Rp. 17.362.608.570,-

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