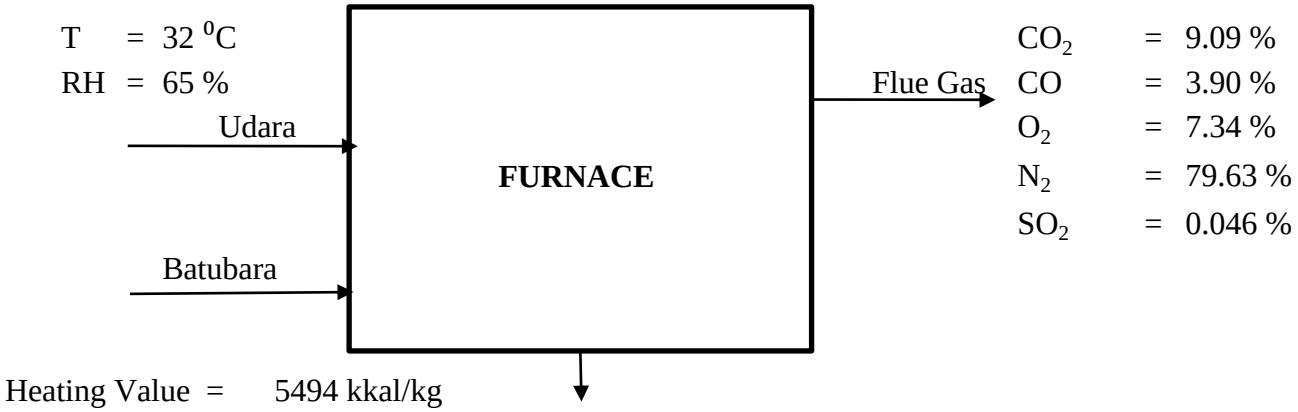

Analisis Proksimate		
Fixed Carbon	=	64.57 %
Volatile Matter	=	21.67 %
Moisture	=	9.76 %
Ash	=	4.00 %
Total	=	100 %

Analisis Ultimate		
Carbon	=	75.64 %
Hidrogen	=	4.81 %
Oksigen	=	18.17 %
Nitrogen	=	1.04 %
Sulfur	=	0.34 %
Total	=	100 %

1 Menentukan basis

Basis perhitungan = 100 lb batubara

Carbon	=	75.64 %	x	100 lb	=	75.64 lb
Hidrogen	=	4.81 %	x	100 lb	=	4.81 lb
Oksigen	=	18.17 %	x	100 lb	=	18.17 lb
Nitrogen	=	1.04 %	x	100 lb	=	1.04 lb
Sulfur	=	0.34 %	x	100 lb	=	0.34 lb
Total	=	100 %			=	100 lb

2 Menghitung Berat Refuse

C content in refuse = 12.4 %

Ash content in refuse = 87.6 %

Berat refuse = $300 \text{ gr} \left| \frac{0.002205 \text{ lb}}{1 \text{ gr}} \right.$

= 0.6615 lb

C in Refuse = 12.4 % x 0.6615 lb
= 0.0820 lb

Ash in refuse = 87.6 % x 0.6615 lb
= 0.5795 lb

• Komposisi in Refuse

C content = 0.0820 lb
Ash in Refuse = 0.5795 lb
Total = 0.6615 lb

3 Carbon Balance

C in BB = C in Flue Gas + C in Refuse
C Flue Gas = C in BB - C in Refuse
= 75.64 lb - 0.0820 lb
= 75.5560 lb
= 6.2963 lbmol

Total C in Flue Gas

CO_2 = 9.09 %
CO = 3.9 %
Total 13 %

$$\text{Total Flue Gas} = \frac{100\ \%}{13\ \%} \times 6.2963 \text{ lbmol}$$
= 48.4930 lbmol

CO_2	=	9.09 %	x	48.4930 lbmol	=	4.4075 lbmol	x	44	=	193.9313 lb
CO	=	3.90 %	x	48.4930 lbmol	=	1.8888 lbmol	x	28	=	52.8865 lb
O_2	=	7.34 %	x	48.4930 lbmol	=	3.5579 lbmol	x	32	=	113.8538 lb
N_2	=	79.63 %	x	48.4930 lbmol	=	38.6164lbmol	x	28	=	1081.2601 lb
SO_2	=	0.05 %	x	48.4930 lbmol	=	0.0223 lbmol	x	64	=	1.4276 lb
								Total	=	1443.3592 lb

4 Nitrogen Balance

N_2 di udara = N_2 Flue Gas - N_2 batubara

$$N_2 \text{ Flue Gas} = \frac{79.6\ \%}{13\ \%} \times 6.2963 \text{ lbmol}$$
= 38.6164 lbmol

N_2 batubara = 0.0371 lbmol

N_2 di udara = 38.6164 lbmol - 0.0371 lbmol
= 38.5793 lbmol

5 Oksigen Balance

$$O_2 \text{ di Udara} = \frac{21}{79} \times 38.5793 \text{ lbmol}$$
= 10.2553 lbmol

O_2 in CO = 1 x 1.8888 lbmol = 0.9444 lbmol

O_2 in CO_2 = 4.4075 lbmol

O_2 bebas = 3.5579 lbmol

O_2 dry FG = O_2 in CO + O_2 in CO_2 + O_2 bebas

= 8.9099 lbmol

O_2 Net H_2 = O_2 di Udara - O_2 dry FG

= 10.2553 lbmol - 8.9099 lbmol

= 1.3454 lbmol

6 Hidrogen Balance

- Moisture di Udara

T = 32 ^{0}C (Asumsi)

RH = 65 %

H = 0.0318 lbmol H2O/ lbmol udara

Moisture di Udara = 0.0318 lbmol H2O/ lbmol udara x 48.8345 lbmol

= 1.5529 lbmol

$$\text{Free Moisture} = \frac{9.76 \text{ lb}}{18 \text{ lb/lbmol}} = 0.5422 \text{ lbmol}$$

$$H_2 \text{ dari batubara} = \frac{4.81 \text{ lb}}{2 \text{ lb/lbmol}} = 2.4040 \text{ lbmol}$$

Net H_2

$$H_2 + 1/2\ O_2 \longrightarrow H_2O$$

2.6908 1.3454 2.69078 lbmol

Net H_2 = 2.6908 lbmol x 2 lb/lbmol

= 5.3816 lb

Analisa Ultimate		
C	75.64 lb	75.6 %
N_2	1.04 lb	1.04 %
S	0.34 lb	0.34 %
Free Moisture	9.76 lb	9.76 %
Net H_2	5.38 lb	5.38 %
Combined water	7.84	7.84 %
Total	100 lb	100 %

- Hidrogen in FG = Net H_2 + Free Moisture + Combined Water + H_2 di Udara

$$H_2 \text{ in combined water} = \frac{7.84 \text{ lb}}{18} = 0.4356 \text{ lbmol}$$

$$H_2 + 1/2\ O_2 \longrightarrow H_2O$$

0.436 0.2178 0.436 lbmol

H_2 Free Moisture $= \frac{9.76 \text{ lb}}{18} = 0.5422$ lbmol

$$H_2 + 1/2\ O_2 \longrightarrow H_2O$$

0.5422 0.2711 0.5422 lbmol

H_2 di Udara

$$H_2 + 1/2\ O_2 \longrightarrow H_2O$$

1.5529 0.7765 1.5529 lbmol

H_2 in FG = 2.6908 lbmol + 0.5422 lbmol + 0.4356 lbmol + 1.5529 lbmol
= 5.2215 lbmol

H_2O in Flue Gas

$$H_2 + 1/2\ O_2 \longrightarrow H_2O$$

5.2215 2.6108 5.2215 lbmol

H_2O in Flue Gas = 5.2215 lbmol x 18 lb/lbmol
= 93.9874 lb

7 **Tabel Neraca Massa**

INPUT			OUTPUT		
BB	=	100 lb	Dry Flue Gas	=	1443.3592 lb
Udara	=	1408.3882 lb	Refuse	=	0.6615 lb
H_2O di Udara	=	27.9529 lb	H_2O in Flue Gas	=	93.9874 lb
Total	=	1536.341081 lb		=	1538.0082 lb

8 Menghitung Enthalpy Product

Enthalpy of products (sumber : Olaf A Hougen, hal : 354)

CO_2

$$H = 1.9992 \text{ kmol} \times \left\{ 6.339 \left(T - 298 \right) + \frac{0.01014}{2} \left(T^2 - 298^2 \right) - \frac{3.415}{3} 10^{-6} \left(T^3 - 298^3 \right) \right\}$$

CO

$$H = 0.8567 \text{ kmol} \times \left\{ 6.350 \left(T - 298 \right) + \frac{0.001811}{2} \left(T^2 - 298^2 \right) - \frac{0.2675}{3} 10^{-6} \left(T^3 - 298^3 \right) \right\}$$

O_2

$$H = 1.6138 \text{ kmol} \times \left\{ 6.117 \left(T - 298 \right) + \frac{0.003167}{2} \left(T^2 - 298^2 \right) - \frac{1.005}{3} 10^{-6} \left(T^3 - 298^3 \right) \right\}$$

N_2

$$H = 17.5161 \text{ kmol} \left\{ 6.457 \left(T - 298 \right) + \frac{0.001389}{2} \left(T^2 - 298^2 \right) - \frac{0.069}{3} 10^{-6} \left(T^3 - 298^3 \right) \right\}$$

SO_2

$$H = 0.0101 \text{ kmol} \times \left\{ 6.945 \left(T - 298 \right) + \frac{0.01001}{2} \left(T^2 - 298^2 \right) - \frac{3.794}{3} 10^{-6} \left(T^3 - 298^3 \right) \right\}$$

Jadi,

$$\sum H_p = 141.15706 \left(T - 298 \right) + 0.0386 \left(T^2 - 298^2 \right) - 3.3084 \times 10^{-6} \left(T^3 - 298^3 \right)$$

$$= 141.1571\ T + 0.0386\ T^2 - 3.3084 \times 10^{-6}\ T^3 - 45405.086$$

9 Menghitung Enthalpy Batubara

HV Batubara = 5494 kkal/kg

Berat batubara = 3 kg

$$Q = m \times HV$$
$$= 3 \text{ kg} \times 5494 \text{ kkal/kg}$$
$$= 16482 \text{ kkal}$$

10 Menghitung Entalpi Udara

Untuk menentukan Q_{udara} digunakan data sebagai berikut :

Temperatur standar = 25 ^oC = 298 K

Temperatur batubara = 32 ^oC = 305 K

Menentukan Cp komponen reaktan dengan menggunakan rumus :

$$Cp = a + b/2(T_2+T_1) + c/3(T_2^2+T_2T_1+T_1^2)$$

Konversi mol yang satuan nya lbmol ke kmol :

Udara = 48.835 lbmol $\left|\frac{0.45359 \text{ kmol}}{1 \text{ lbmol}}\right.$

= 22.1510 kmol

Diketahui :

A = 6.3860

B (x 10^{-3}) = 1.762 (Sumber : Olaf A Hougen, hal : 255)

C (x 10^{-6}) = -0.266

Cp = 6.3860 kkal/kmol K

Q = n x Cp x ΔT

= 22.1510 kmol x 6.3860 kkal/kmol K x (305 K - 298 K)

= 990.1921 kkal

11 Menghitung Entalpi Penguapan H_2O pada Udara

ΔH_1 = 9717 kkal/kmol (Sumber : Olaf A hougen, Tabel 26 : hal 274)

Temperatur didih air, T_b = 100 °C = 373 K

Temperatur kritis air, Tc = 1165.1 °R = 647.28 K

Temperatur udara, T_{udara} = 32 °C = 305 K

$T_{r1} = T_b/T_c$

$= \frac{373 \text{ K}}{647.28 \text{ K}}$

= 0.5763 K

$T_{r2} = T_{udara}/T_c$

$= \frac{305 \text{ K}}{647.28 \text{ K}}$

= 0.4712 K

Rumus mencari panas penguapan air di udara

$$\frac{\Delta H_2}{\Delta H_1} = \left(\frac{1 - T_{r2}}{1 - T_{r1}}\right)^{0.28}$$ (Sumber : Olaf A hougen, hal 281)

$$\frac{\Delta H_2}{9717} = \left(\frac{1 - 0.4712 \text{ K}}{1 - 0.5763 \text{ K}}\right)^{0.28}$$

ΔH_2 = 10338.67 kkal/kmol

= 10338.67 kkal/kmol x 1.5529 lbmol $\left|\frac{0.4536 \text{ kmol}}{1 \text{ lbmol}}\right.$

= 7282.5667 kkal

Maka,

$\sum H_R$ = Entalpi Batubara + Entalpi Udara + Entalpi Penguapan H_2O pada Udara

= (16482 + 990.1921 + 7282.56669) kkal

= 24754.7588 kkal

12 Menghitung Flame Temperature Teoritis

Maka, Trial temperature = 444 K = 171 ◦C

$\sum H_R = \sum H_p$

$24754.76 = 141.1571\ T + 0.0386\ T^2 - 3.3084 \times 10^{-6}\ T^3 - 45405.086$

$24754.76 = 141.157 \times 444 + 0.0386\ (444^2) - 3.3084 \times 10^{-6}\ (444^3) - 45405.086$

$24754.76 = 24588.519$

Maka untuk mendapatkan flame temperature teoritis dapat interpolasi setiap komponen product dengan menggunakan cp pada Olaf A Hougen. Tabel 19, hal : 258

Contoh :

CO_2

$x = 171$ ◦C

$x_1 = 100$ ◦C $\quad y_1 = 9.251$ kkal/kmol K (Sumber : Olaf A Hougen, Tabel 19, hal : 258)

$x_2 = 200$ ◦C $\quad y_2 = 9.701$ kkal/kmol K

$$y = y_1 + \frac{x - x_1}{x_2 - x_1}\ y_2 - y_1$$

$$= 9.251 + \frac{171 - 100}{200 - 100}\ (9.701 - 9.251)$$

= 9.5705 kkal/kmol K

Jadi,

$cp\ CO_2$ = 9.5705 kkal/kmol K

$cp\ CO$ = 7.0071 kkal/kmol K

$cp\ O_2$ = 7.1526 kkal/kmol K

$cp\ N_2$ = 6.989 kkal/kmol K

$cp\ SO_2$ = 10.134 kkal/kmol K

$\sum H_p$ = [(mol CO_2 x cp CO_2) + (mol CO x cp CO) + (mol O_2 x cp O_2) + (mol N_2 x cp N_2) + (mol SO_2 x cp SO_2)] x (T - 298)

= [(1.9992 x 9.5705) + (0.8567 x 7.0071) + (1.6138 x 7.1526) + (17.516 x 6.989) + (0.0101 x 10.134)] x (T - 298)

$24754.76 = 159.20335 \times (T - 298)$

24754.76	=	159.2033 T	-	47442.597
24754.76	+	47442.597	=	159.2033 T
		72197.36	=	159.2033 T
		453.49 K	=	T
		180.49 ◦C	**=**	**T**

-

6.9302
6.9805
6.4570
6.3860

Untuk menentukan Q_R digunakan data sebagai berikut :

Temperatur standar = 25 ^oC 298

Temperatur batubara = 32 ^oC 305

Menentukan Cp komponen reaktan dengan menggunakan rumus :

$$Cp = a + b/2(T_2+T_1)+c/3(T_2^2+T_2T_1+T_1^2)$$

Konversi mol yang satuan nya lbmol ke kmol :

H_2 = 1.0904 lbmol | 0.4536 kmol / 1 lbmol

= 0.4946 kmol

Tabel Cp Masing-Masing Reaktan

Komponen	A	B (x 10^{-3})	C (x 10^{-6})
H_2	6.9460	-0.196	0.4757
O_2	6.1170	3.167	-1.005
N_2	6.4570	1.389	-0.069
Udara	6.3860	1.762	-0.266

Sumber : Olaf A Hougen, hal : 255

Setelah diketahui nilai konstanta *heat capacity* , maka dapat ditentukan nilai Cp dengan menggunakan rumus tersebut. Dan dapat dihitung entalpi reaktan dengan menggunakan rumus : $Q = n \times Cp \times \Delta T$

Tabel Entalpi Masing-Masing Reaktan

Komponen	mol (kmol)	Cp (kkal/lbmol K)	Q (kkal)
H_2	1.0904	6.9302	52.8971
O_2	0.2576	6.9805	12.5879
N_2	0.0168	6.4570	0.7615
C	2.859	0.147	2.9420
S	0.005	0.1765	0.0060
Udara	22.151	6.3860	990.1921
Total			1059.3865