Appendix A: Calculation of Flue Gas Composition

Consider 100 kg of biomass (pine wood) with an Ultimate Analysis on a dry ash free basis given in Table A.1.

This calculation assumes that all the carbon is burned i.e. there is no carbon in the ash or carbon monoxide formed. If there is the unburned carbon has to be subtracted from the value of carbon in the above table. Also that the S, N and Cl are negligible and there is no ingress of N_2 in the flue or sampling system. Moisture content given in the Proximate Analysis has to be allowed for in the calculation as well.

Assume the combustion reactions are

$$C + O_2 = CO_2$$

$$2\,H_2 + O_2 = 2\,H_2O$$

$$\text{Oxygen required for stoichiometric combustion} = 4.33 + 1.6 - 1.3 = 4.63\text{kg-mol}$$

$$\text{Air requirement} = [4.63 \times 100 \times 22.41\,]/[\,21] = 494.1\ \text{m}^3 \text{ at NTP}$$

Composition of the **dry flue gas** from the stoichiometric combustion of 1 kg of biomass:

N_2 from theoretical air $= 4.94 \times 0.79 = 3.90\ \text{m}^3$.
N_2 from biomass $= 0.001 \times 0.224 = 0.0002\ \text{m}^3$.
CO_2 from biomass $= 4.33 \times 0.224 = 0.97\ \text{m}^3$.
Total amount of **dry flue gas** per 1 kg wood $= 4.872\ \text{m}^3$.

If the concentration in the wet flue gas is required then the water content has to be included in the above calculation.

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Table A.1 Calculation of flue gas composition

Element	Molecular weight	Mols O_2 required
C, 52.00	12	4.33
H, 6.20	2	1.6
O, 41.60	32	−1.3
N, 0.2	28	

Therefore % $CO_2 = 0.97/4.872 = 19.91$ assuming stoichiometric combustion (0 % O_2).

For 20 % excess air = 16.6 % CO_2
For 40 % excess air = 14.2 % CO_2
For 50 % excess air = 13.27.

Appendix B: Gaseous Emissions Conversion Table

A Conversion Chart is given below. The unit used is the Normal m^3 (Nm^3) which is commonly used by metric countries and the power industry generally. The reference temperature is 0 °C and 1 bar pressure. Other countries, such as the US EPA, use 20 °C and some tables and converters available on the web use 25 °C. Corrections have to be applied at altitudes above sea level. Note that NO_x is treated as NO_2.

To convert from 1 ppmv	To mg Nm^3
NO_x	2.05
NO	1.34
CO	1.25
SO_2	2.86
HCl	1.63
NH_3	0.76
HCN	2.86

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Appendix C: Physical and Thermal Properties of Biomass

Some typical values are given here, but they depend on the moisture content and the exact structure of the biomass.

Pine	
Density	550 kg/m^3
Thermal conductivity	0.12 W/mK
Heat capacity	1670 J/kgK
Straw	
Density	400 kg/m^3
Thermal conductivity	0.1 W/mK
Heat capacity	350 + 2T J/kgK

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