

Extractive determination of the flue gas composition in a recovery boiler furnace

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Abstract

Experimental determination of the gas composition in full scale furnaces is important for the understanding of the kinetics of the gas phase reactions and the formation of different intermediates in the combustion process. Measuring the gas composition in the furnace area sets certain requirements on the sampling method. Challenges when measuring in the furnace area are e.g. high temperatures, particles in the flue gas and the complexity of the gas composition. A gas sampling probe for determining the flue gas composition in the furnace area of a recovery boiler was developed. The developed gas sampling probe is based on dilution of the gas sample in the probe tip with nitrogen, to quench the ongoing combustion reactions in the flue gas. To determine the dilution ratio a tracer gas, sulfur hexafluoride (SF_6), was added to the dilution gas. The developed gas sampling probe was tested in a large recovery boiler and was connected to a Fourier Transform Infrared (FTIR) analyzer, two gas chromatographs (GC) and an oxygen analyzer.

1 Construction of the probe

The gas probe is based on diluting the gas sample in the measurement point. Dilution of the flue gases has many advantages. The gas sample is rapidly quenched and the reactions in the gas sample are stopped. The risk of water condensation and precipitation of salts decreases, as the condensation temperature is lowered in the diluted gas sample. Catalytic reactions between the probe material and the diluted gas decrease due to the lower temperature and the lower concentrations of gas components in the diluted sample. A cross-section picture of the gas sampling probe can be seen in figure 1. The probe is cooled by air. Adequate cooling is crucial to protect the probe from the hot and corrosive environment in the recovery boiler furnace. The flue gas sample is diluted in the probe tip with nitrogen to stop the ongoing combustion reactions. The nitrogen gas trickles through a porous pipe in the probe tip. The flow of the dilution gas through the porous pipe prevents the flue gas sample from coming in contact with the probe walls. The gas sample is cooled to about 200°C . The probe does not demand any filter in the probe tip, because only a small amount of flue gas is drawn from the furnace and mixed with the dilution gas. The particles are removed from the diluted gas sample at the back end of the probe with a fine filter. At this point the gas sample is already diluted and quenched and therefore there is no significant risk for secondary reactions to occur. The center pipe, where the gas sample is transported, is electrically heated to 200°C to avoid condensation reactions from occurring. Three thermocouples were placed in the probe center pipe, to ensure the right temperature for the gas sample in the probe.

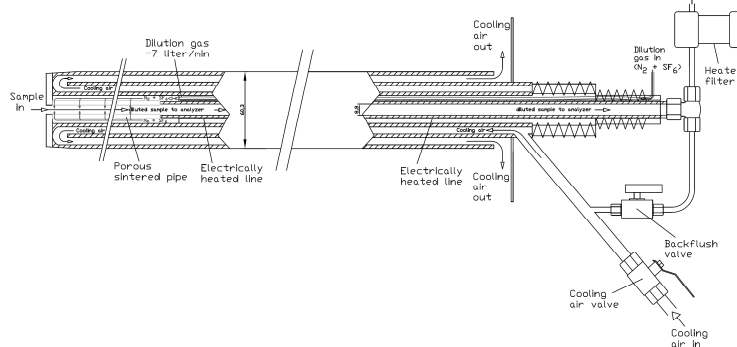


Figure 1. Cross-section of the probe

2 Determination of the dilution ratio

When using the dilution technique the dilution ratio must be accurately determined. SF_6 was added as a tracer gas in the dilution gas to determine the degree of dilution and as an alternative method the flows of the dilution

gas and gas sample were controlled. The dilution rate is determined by measuring the tracer gas concentration in the dilution gas and in the diluted gas sample. SF_6 suits for this application because it is: chemically inert, not present in the flue gas and thermally stable. SF_6 has also a high absorption of infrared light which makes it easy to identify and quantify with a FTIR-analyzer. Because of SF_6 's strong absorption of infrared light only a low concentration (2-3 ppm) is needed in the dilution gas.

3 Setup of the measurement equipment

The measurement equipment used for measuring the gas composition is shown in figure 2. It consists of the probe and the sample line connected to the analyzers. The probes and sample lines task are to transport a representative gas sample from the measurement point to the analyzers and to protect the analyzers by removing particles from the gas sample. The sample line was heated to 180°C to avoid condensation reactions. The flows of the quenching gas and the tracer gas were adjusted by mass flow regulators. The analyzers consisted of two FTIR-analyzers and two gas chromatographs and one oxygen analyzer. The most of the gas components were measured with the FTIR-analyzer. Reduced sulphur compounds and hydrogen were measured with the gas chromatographs.

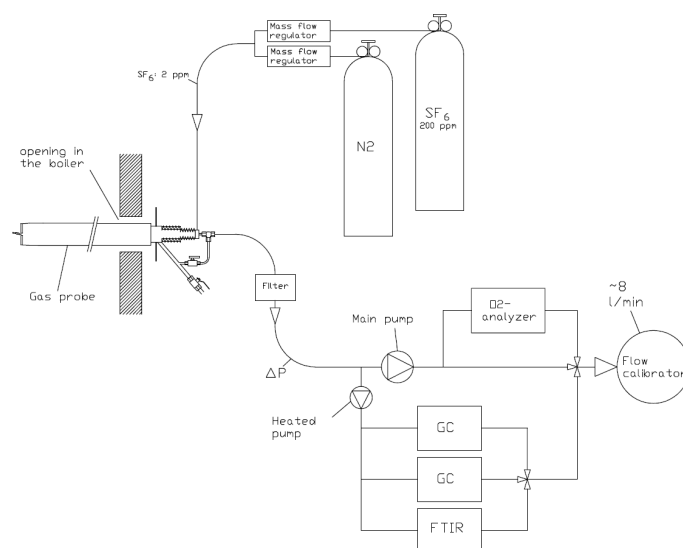


Figure 2. Setup of the measurement equipment

4 Measurements

The measurements were performed in a recovery boiler with a design capacity of 3450 tds/d. The measurements were carried out at four levels in the boiler, from the primary air level to the tertiary air level at two depths: 1m and 2m inside the furnace. The following gas species could be measured: O_2 , H_2O , CO_2 , CO , NO , NO_2 , N_2O , SO_2 , HCl , NH_3 , HCN , CH_4 , C_2H_2 , C_2H_4 , C_2H_6 , C_3H_6 , C_6H_6 , C_6H_{14} , $\text{C}_6\text{H}_5\text{CH}_3$, H_2S , CH_3SH , $\text{C}_2\text{H}_5\text{SH}$, CH_3OH , CH_3CHO , CH_2O , $\text{C}_3\text{H}_4\text{O}$, COS , CH_3SCH_3 , CS_2 , $\text{CH}_3\text{S}_2\text{CH}_3$, CH_3COCH_3 . H_2 could not be determined due to plugging of the column in the GC.

5 Conclusions

Overall, the probe worked well. The continuous measurement time was up to 2h without plugging of the center pipe or overheating of the probe. The quenching of the gas sample worked well and different intermediates could be measured. Improvements have to be done on the determination of the dilution ratio. In some hot measurement points the tracer gas decomposed partly. This can, however, easily be fixed by small modifications to the setup of the equipment.

6 Acknowledgements

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