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In-Flame Measurements on Full-Scale Swirl Stabilized Bio-Dust Burners at Different Operational Conditions

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Supplementary material

This supplementary material serves to introduce the practical methods of the full-scale campaigns. Measurements are carried out at Amager Power Plant unit 1 (AMV1) and Herning Power Plant (HEV) and the methods will be briefly introduced and illustrated below. In addition, the experimental matrix will be presented.

1. Probe Measurement Methods

The probe measurements including both extractive gas methods and optical measurements are all conducted along the centre line of the flame in the flow axial direction. This allows for quick flame mapping and thus leaves time for investigating additional operating conditions. The probe is inserted through the centre core of the burners, replacing the oil-lance as illustrated in Figure 1 for both power plants. Measurements are made in a traversing pattern with a 12-25 cm discretization resulting in good spatial resolution of temperature and gas concentration measurements along the centre line.

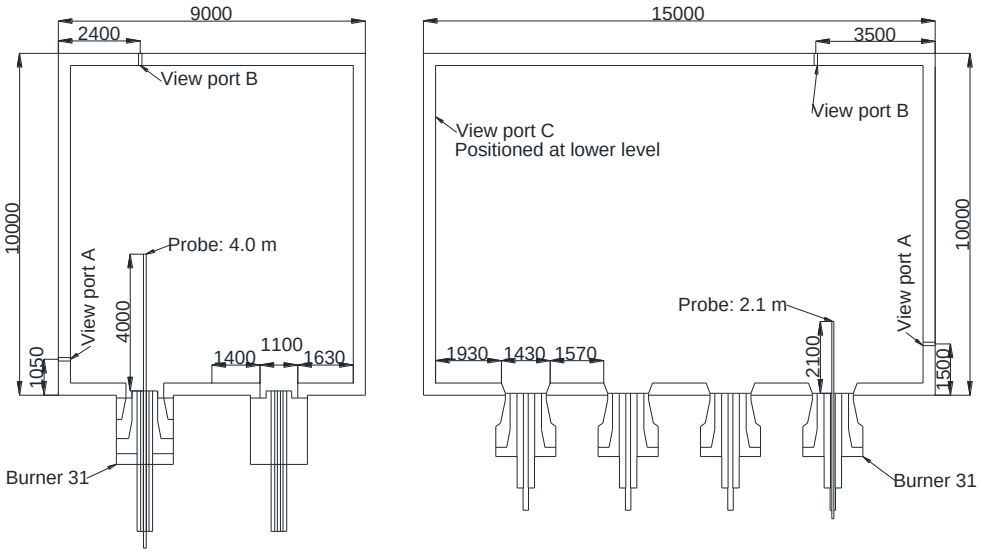

Figure 1: Top view sketches of (left) Amager Power Plant unit 1 and (right) Herning Power Plant. Both illustrated with fully inserted probes. View ports used for optical observations are indicated and labelled alphanumerically. Length scale is given in mm.

The water cooled probe is connected to the analyses equipment as illustrated in Figure 2. The down-stream gas analysis consists of two parallel gas cells for simultaneous UV and IR absorption measurements (H_2O, CO, CO_2, C_2H_2, and CH_4) and a paramagnetic O_2-analyzer all with integrated pressure, flow, and temperature control. The optical signal is transferred via fibre optics to a Bomem Fourier Transformed IR spectrometer for gas temperature analysis.

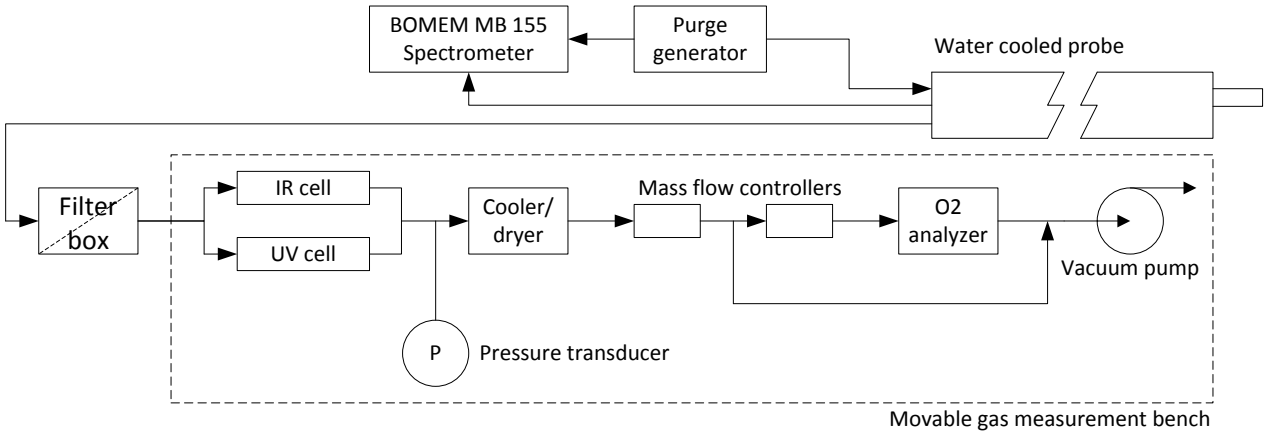

Figure 2: Diagram of the gas sampling and FTIR system for gas species concentration profiles and gas phase temperatures.

2. Optical Observations

Optical observations in both the visual and infrared region were conducted from view ports installed on the side of the furnace, thus, giving visual access perpendicular to the probe and the flow axial direction (through view port A in both AMV1 and HEV, cf. Figure 1). Video observations in the visual spectra provide data on flame stability in the near burner field e.g. if flame lift is occurring as seen in Figure 4 compared to a well attached flame, cf. Figure 3.

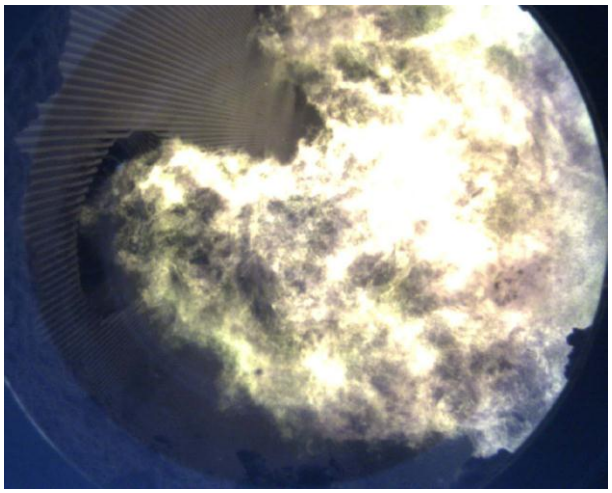

Figure 3: Side port view with the flame well attached to the burner quarl.

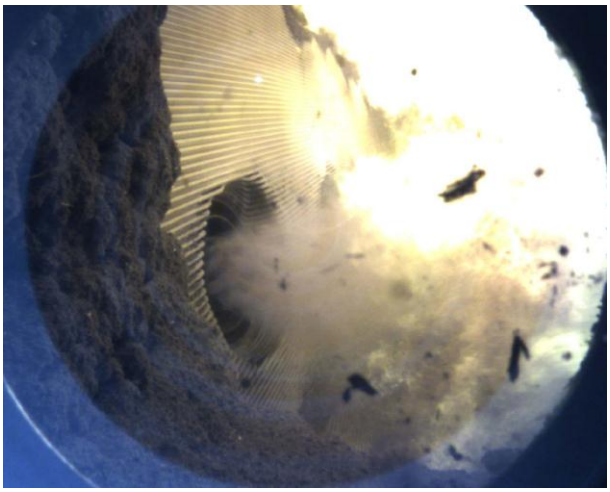

Figure 4: Side port view with flame detachment and flame stabilization approximately 1 meter into the furnace.

Two-line pyrometry is applied on image material obtained in the infrared region for particle cloud surface temperature estimates using laboratory grey body calibration. Figure 5 shows how cold clouds of particles entrain far into the boiler. Cold particle entrainment was found to be sensitive to variations in the fluid dynamics close to the burner mouth, e.g. changing the swirl of the secondary air, and could be correlated to the occurrence of flame lift as seen in Figure 4.

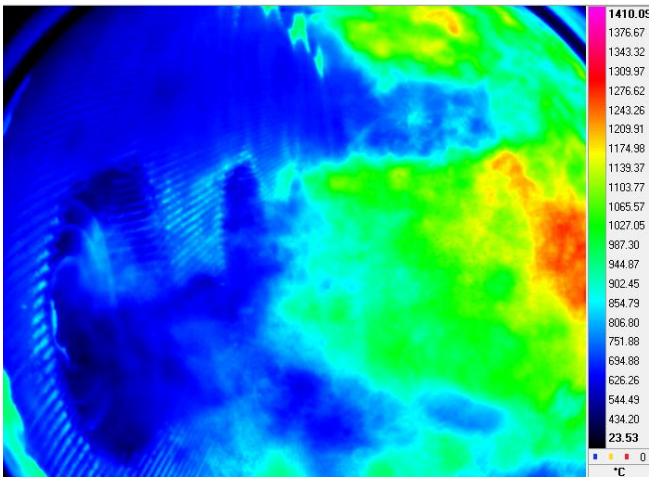

Figure 5: IR image calibrated for particle surface temperature estimations. Temperature scale is given in degree Celsius.

3. Operating Conditions

This section presents the changes to the operational conditions at both Amager Power Plant and Herning Power Plant, Table 1 and 2 respectively. Four reference runs are carried out at each burner to establish a baseline for stable operating conditions. In all cases milled wood pellets is used as primary fuel.

Table 1: Parameter changes at Amager Power Plant.

Exp #	Parameter	Setting			Unit
		Change [%]	Abs	Ref	
1	Secondary air	+20	9.4	7.8	kg/s
2	Secondary air	-17	6.5	7.8	kg/s
3	Air-split	-38	31	50	-
4	Air-split	+12	56	50	-
5	Secondary swirl	-20	80	100	%*
6	Tertiary swirl	-20	80	100	%*
7	Primary air	-5.3	14	15	kg/s
8	Primary air	+6.7	16	15	kg/s
9	Particle size	-21	15	19	%**

*The percentage refers to the physical position of the swirler.
** The percentage refers to the fractional rotational speed of the classifier.

Table 2: Parameter changes at Herning Power Plant.

Exp #	Parameter	Setting			Unit
		Change [%]	Abs	Ref	
1	Particle size	+35	1.3	2	mm*
2	Tertiary swirl	-50	45	90	%**
3	Air-split	+50	0.3	0.15	-
4	Primary air temperature	+40	150	210	^{o}C
5	Load	-33	4.8	6.4	Tons/h

* The distance refers to the gap between the disc in the mill pulverizing the wood pellets.
** The percentage refers to the physical position of the swirler.