PROCESS CHEMISTRY CENTRE

ÅBO AKADEMI UNIVERSITY

COST FP0901 "Biorefinery analytics – Outcomes from COST Action FP0901"
Åbo Akademi, Turku, September 17-18, 2013

Combustion analysis

Mikko Hupa
Åbo Akademi

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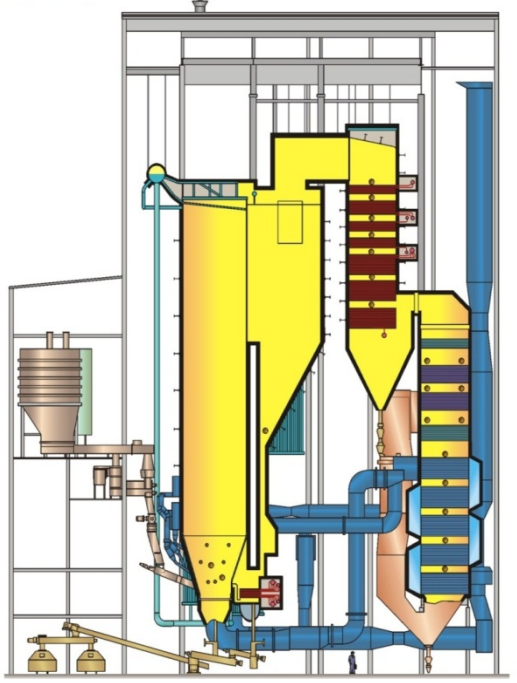
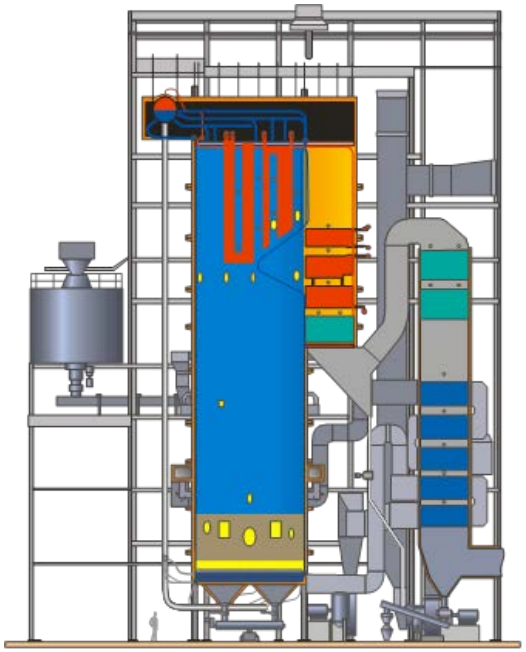
Combustion analysis
- *What goes on in large furnaces?*

Mikko Hupa
Åbo Akademi

- Great interest low grade biomasses and waste derived fuels
- Finland strong on large scale biomass combustion technology
- …Devil in the chemical details:
  - Flue gas emission limits
  - Ash related fouling and corrosion





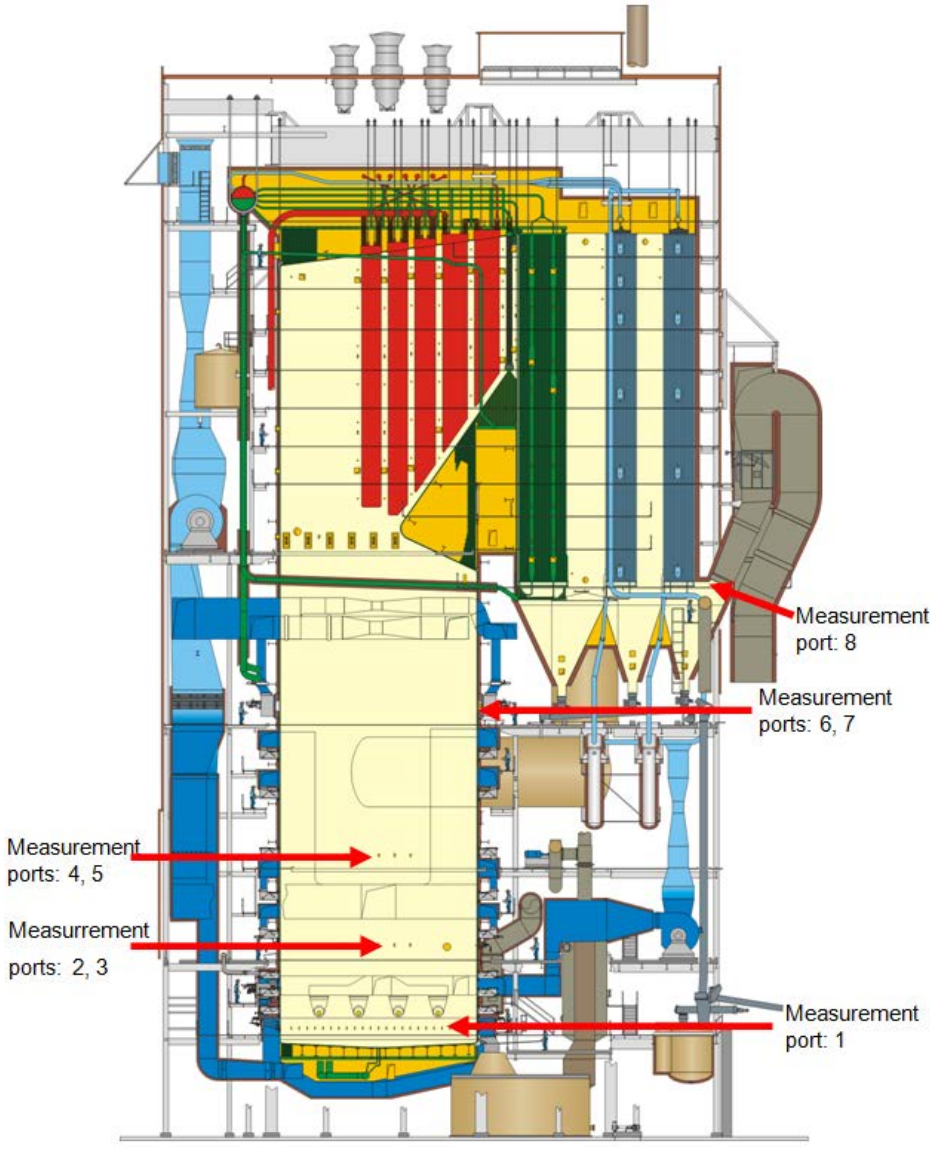
Courtesy by Foster Wheeler and Metso

Black Liquor Recovery Boiler

Fray Bentos, Uruguay (Andritz)

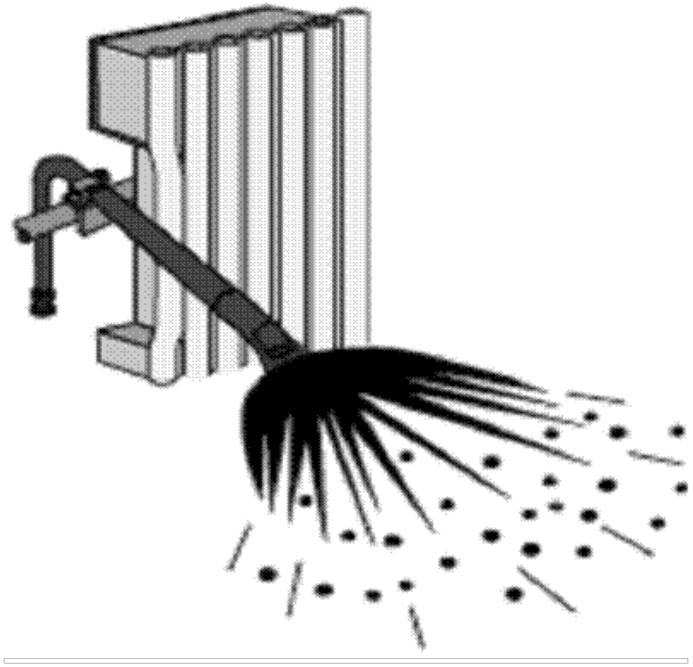
In-Furnace Data from Large Furnaces

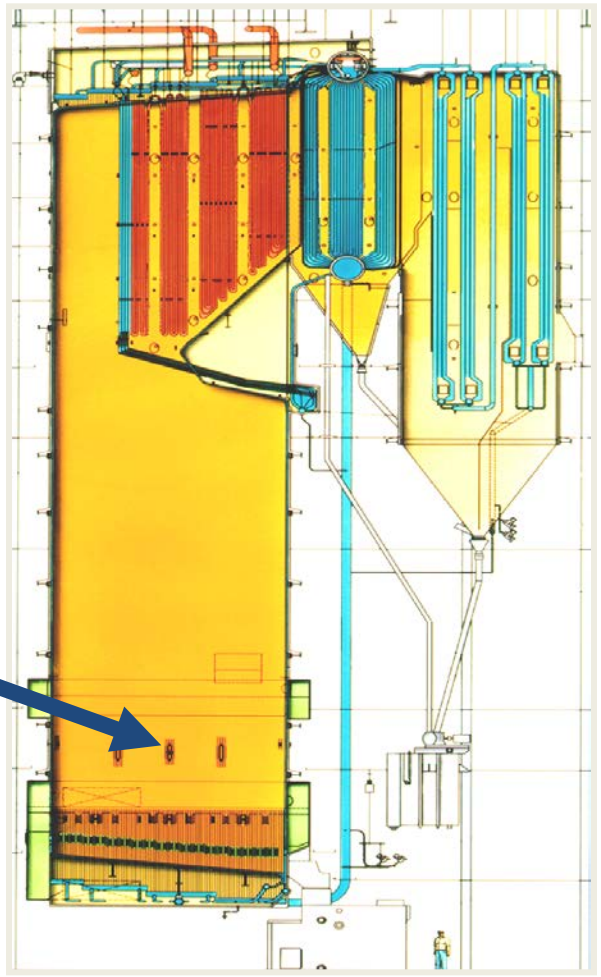
85 m

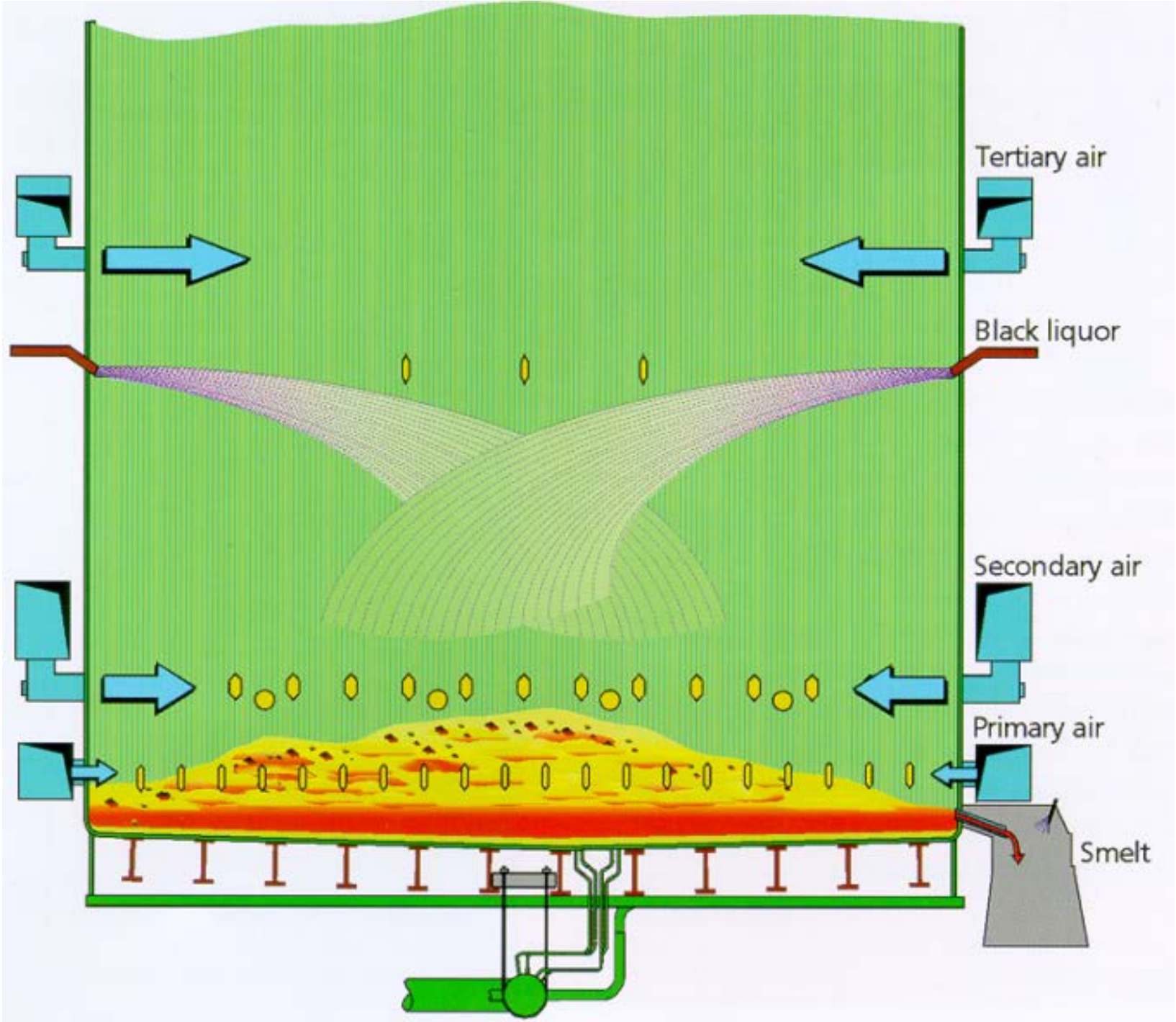


Vainio, E., Brink, A., DeMartini, N., Hupa, M., Vesala, H., Tormonen, K., Kajolinna, T., In-furnace measure-ment of S and N species in a recovery boiler, ”International Chemical Recovery Conference”, TAPPI (2010)

Black Liquor Sprays



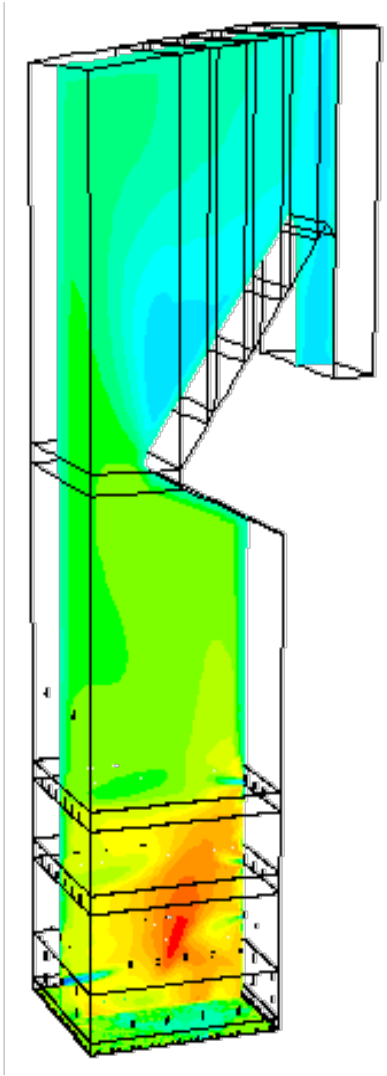



Tertiary air
Black liquor
Secondary air
Primary air
Smelt

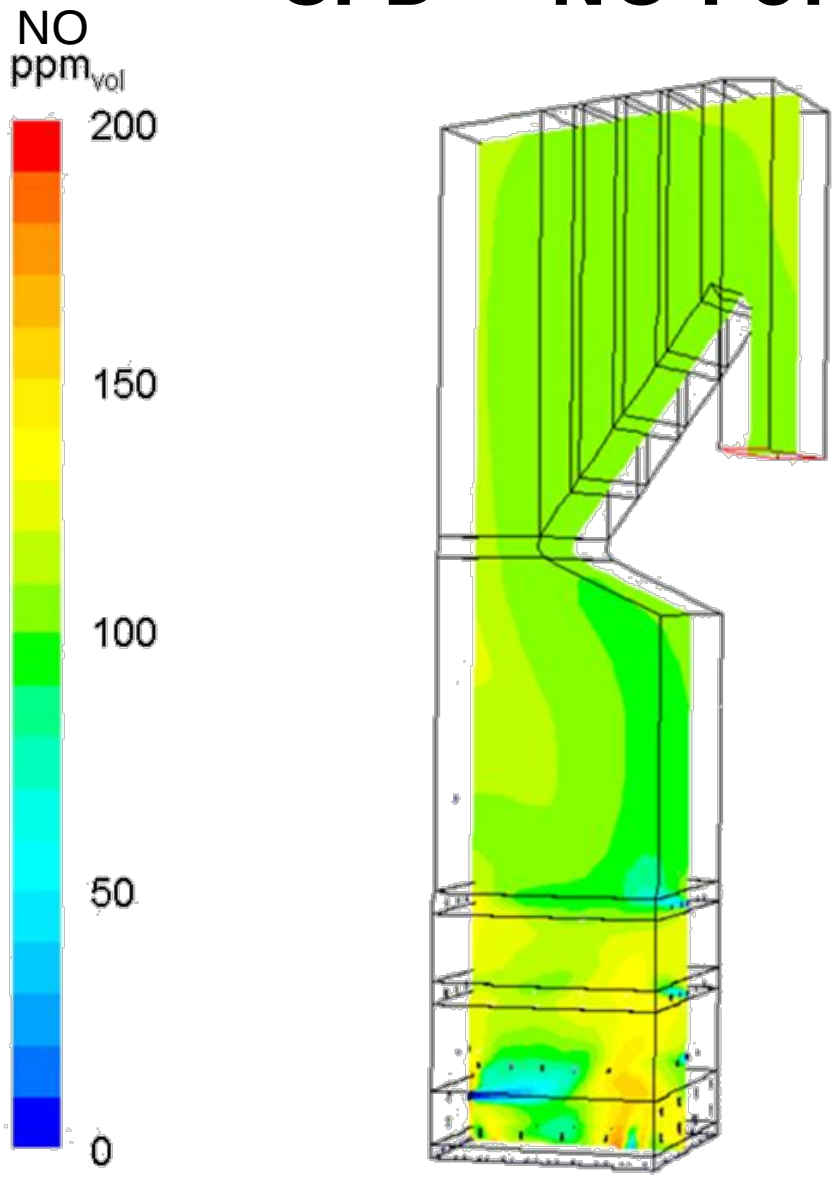
Computational Fluid Dynamics

- Calculating flows in complex geometries
- Based on fundamental flow physics
- Momentum equations solved iteratively in computational cells
- General commercial software available

- Chemical aspects require major additional development



CFD – NO Formation Modelling



Model basis

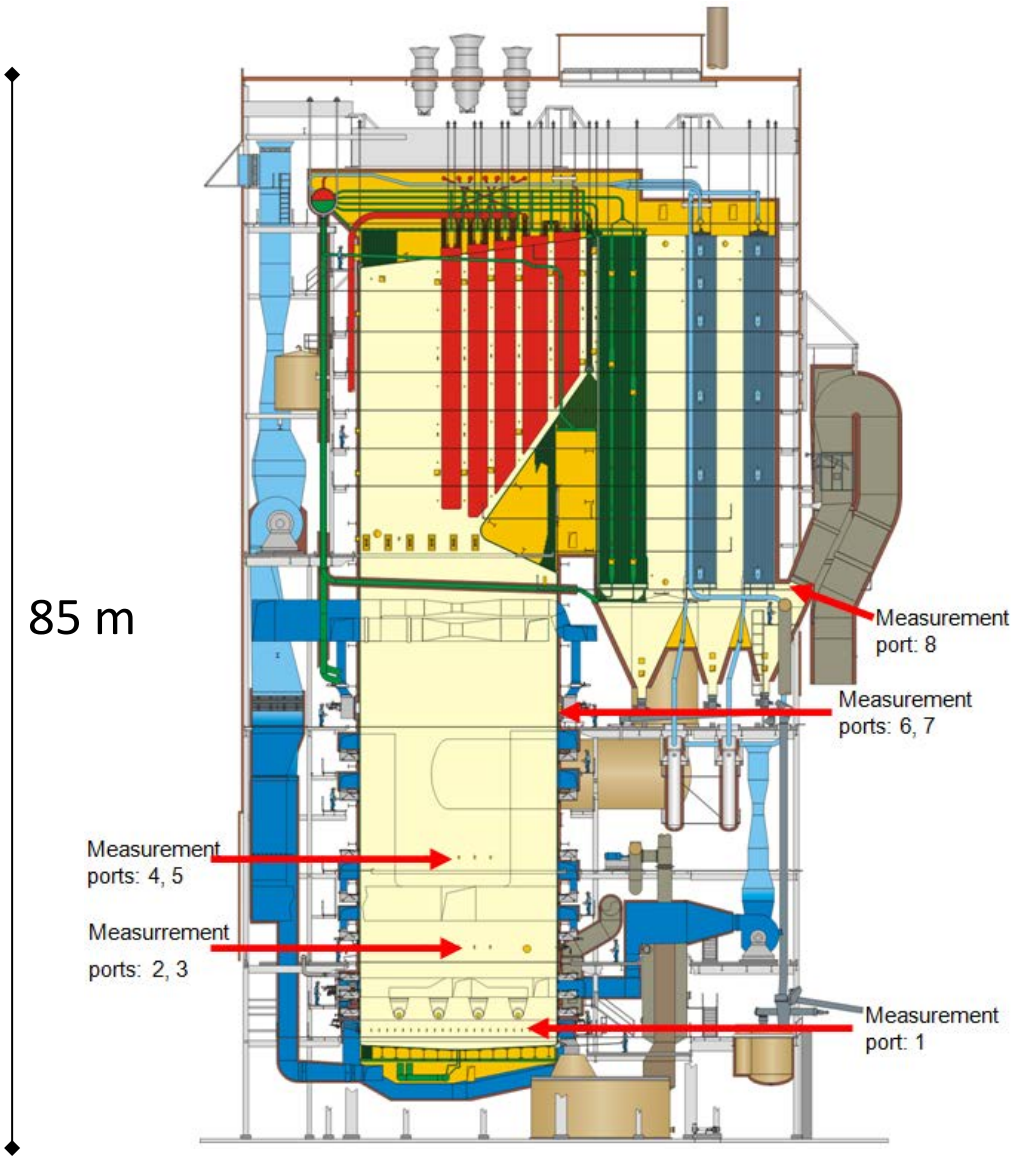
- Fuel bound N released as NH_3
- NH_3 reacts to NO or N_2

Brink et al. 2008

In-Furnace Data from Large Furnaces

Challenges:

- Dimensions (15 m x 15 m)
- 1000 - 1400 C
- Non-transparent (particle radiation)
- Molten particles
- Corrosive
- Gases react in sampling lines



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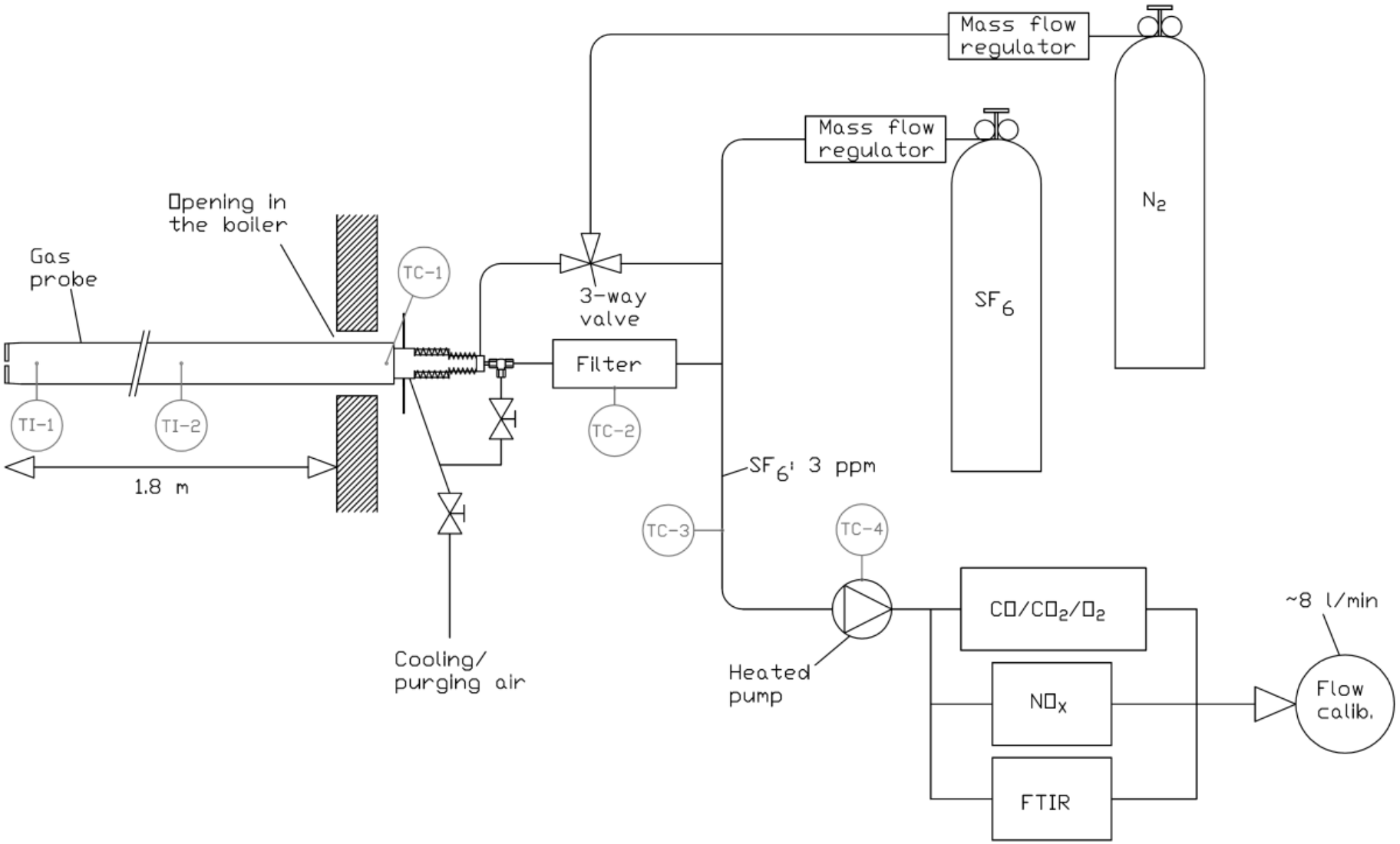
In-Furnace Gas Sampling and Analysis



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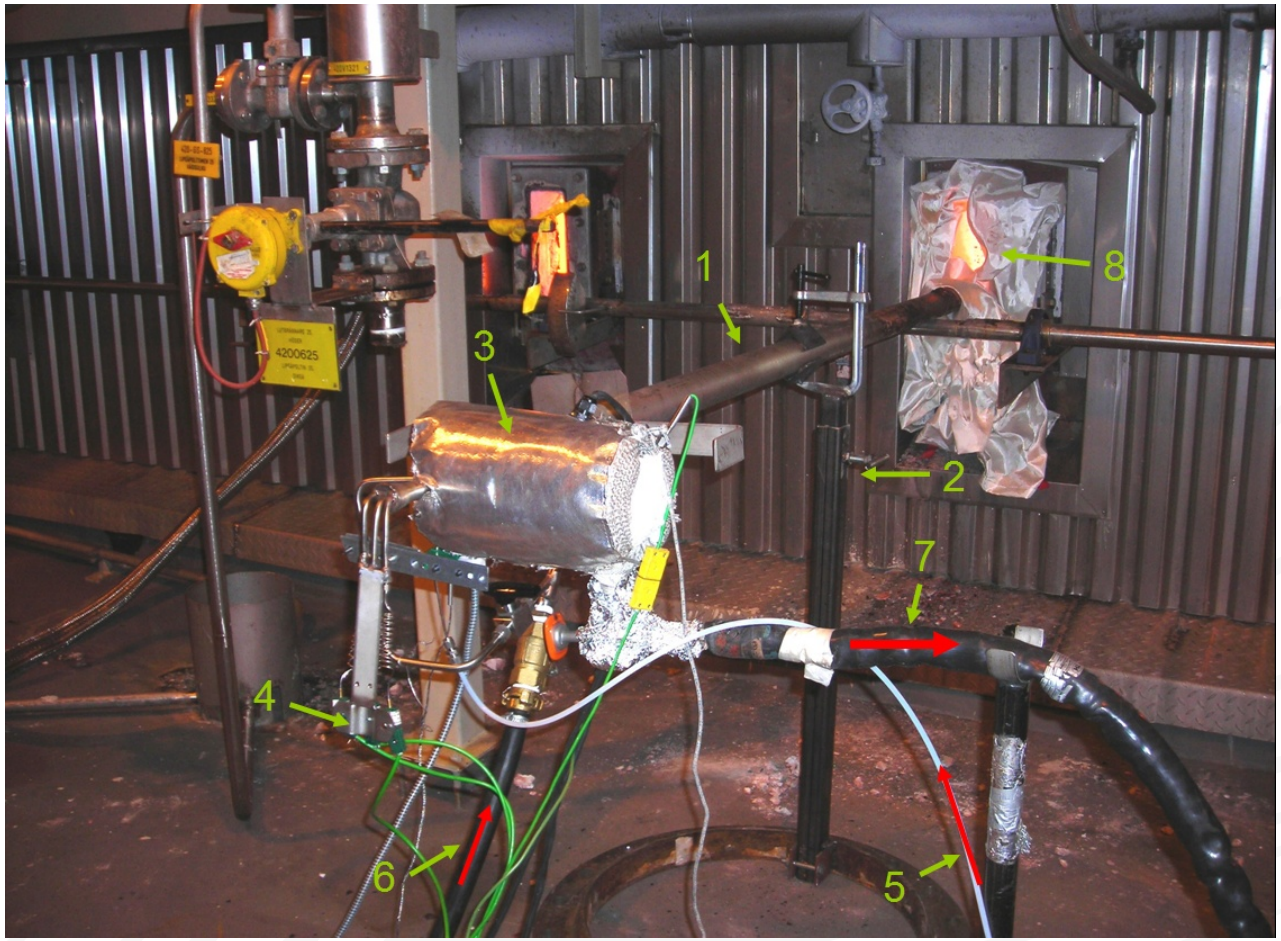
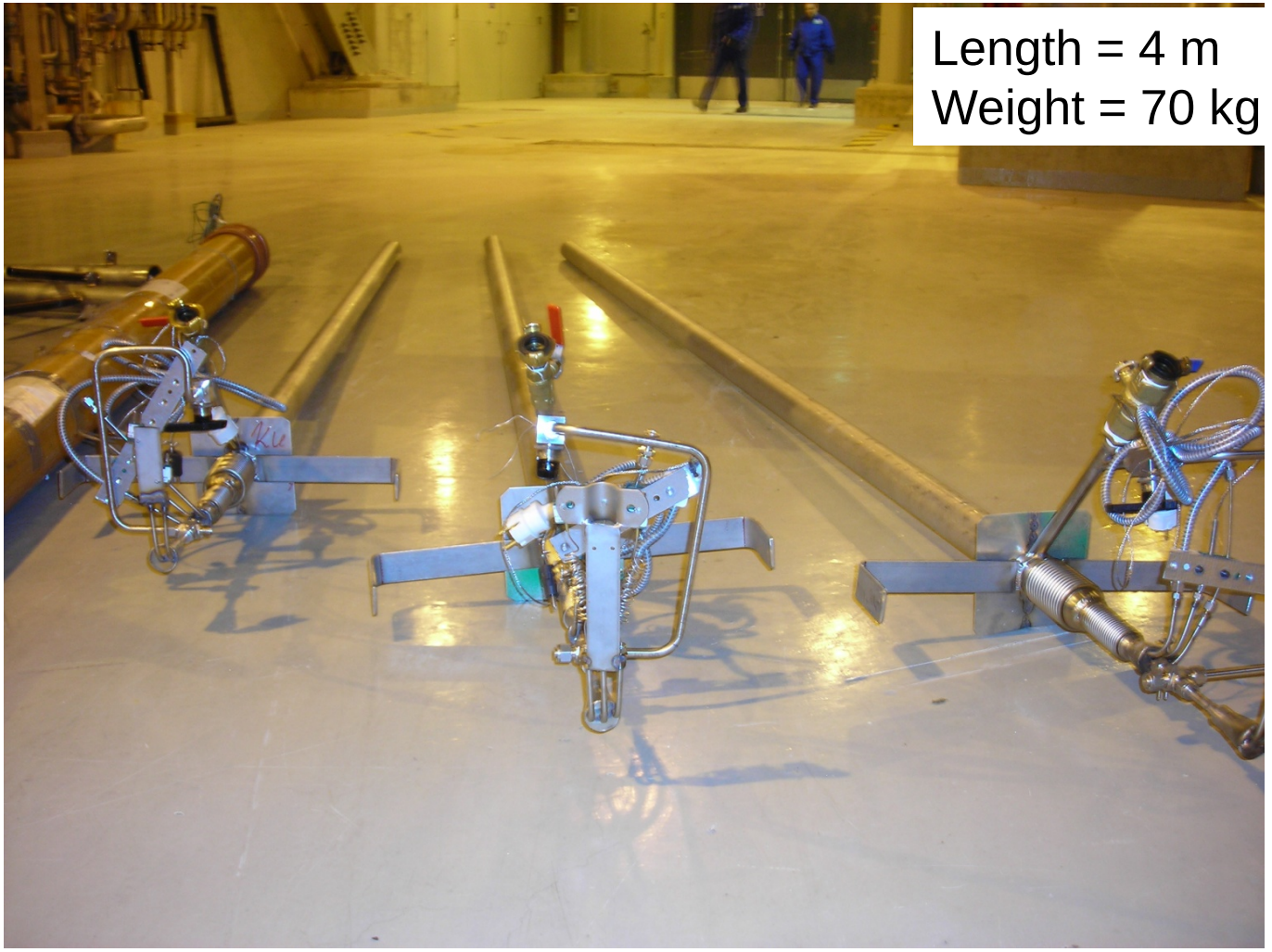
Analyzers

- FTIR
  - NO, NO_2, NH_3, HCN, CO_2, CO, COS, HCl, CS_2, H_2O, CH_4
- O_2 -analyzer
- GC
  - Reduced sulfur species
    - H_2S, CH_3SH, C_2H_6S...

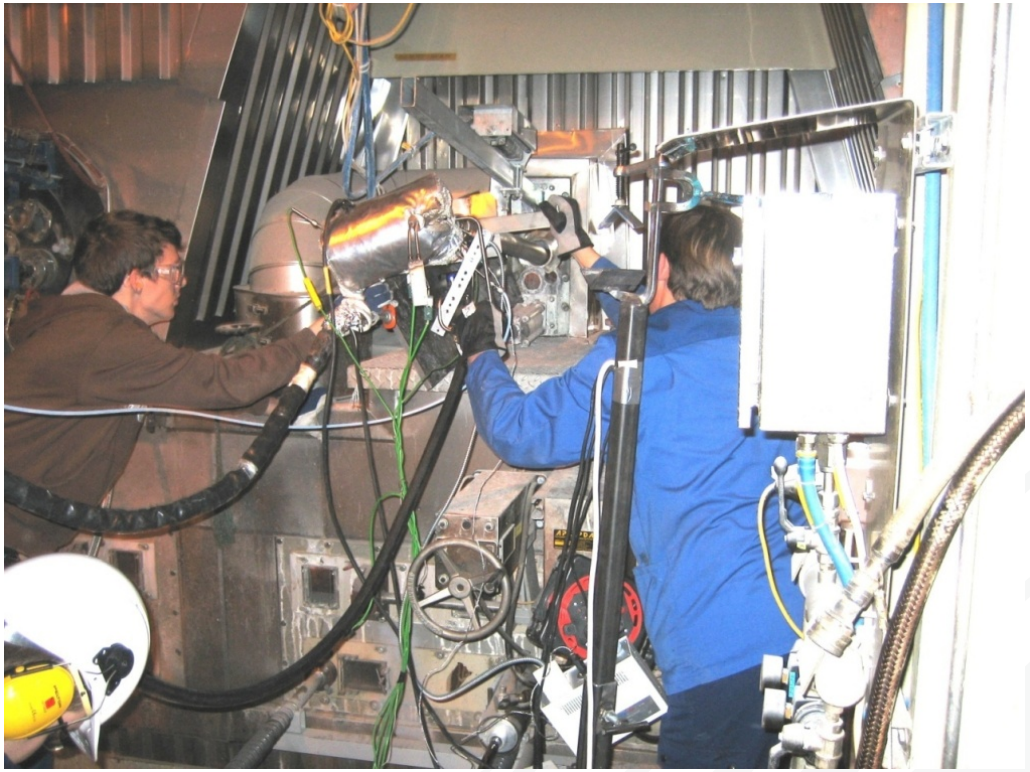
The probe tip 1 m in the furnace

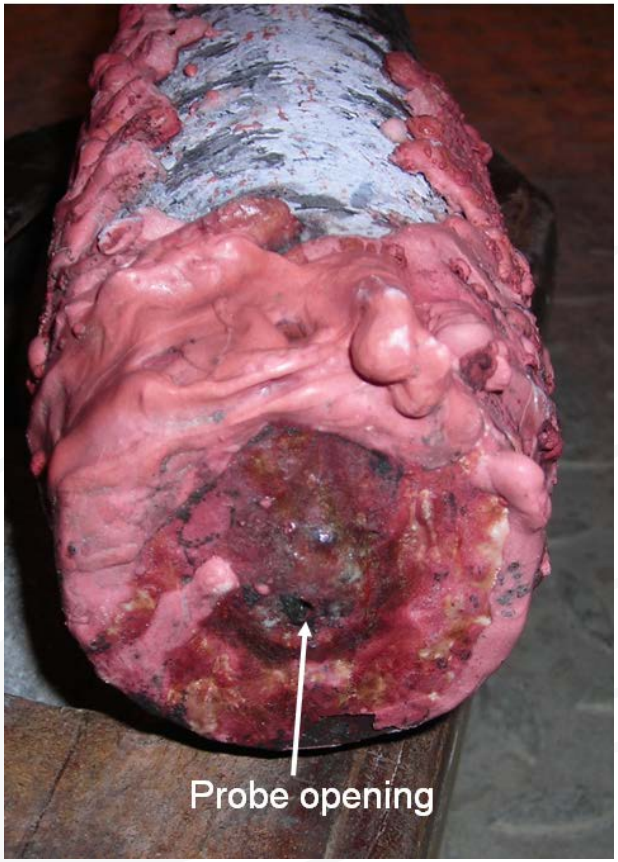


Gas Sampling Probes

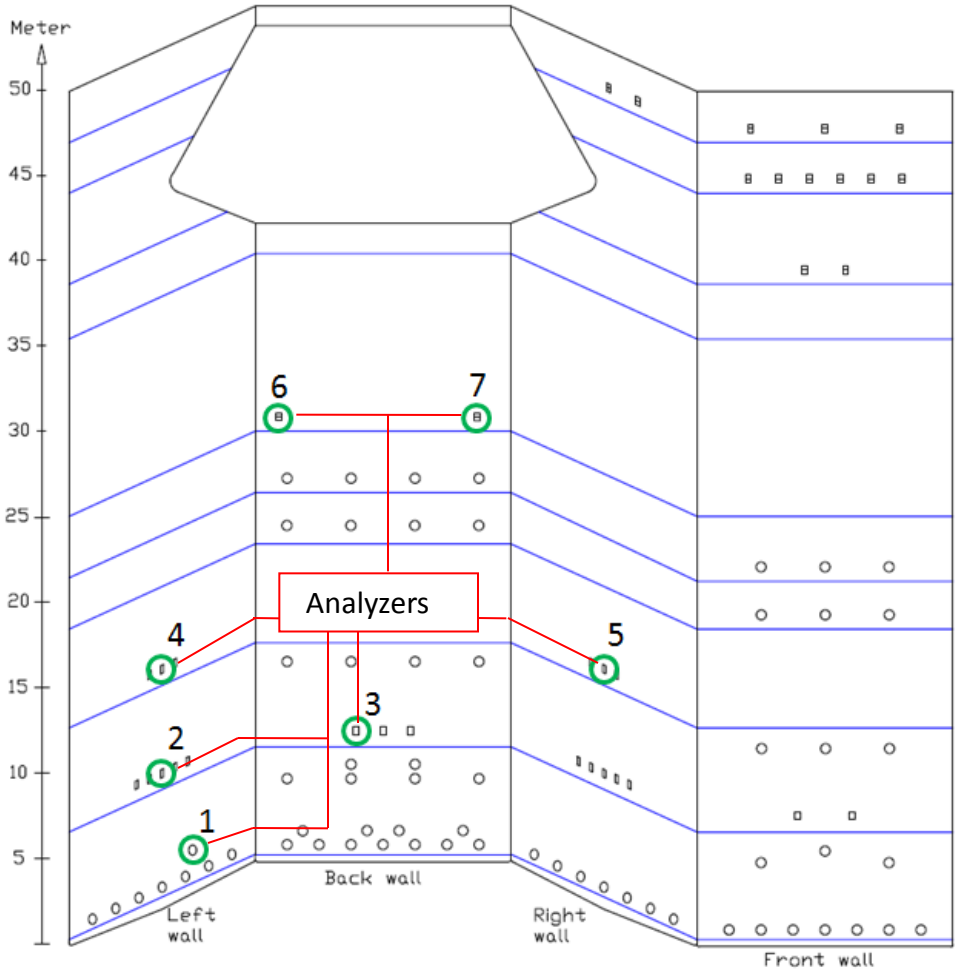


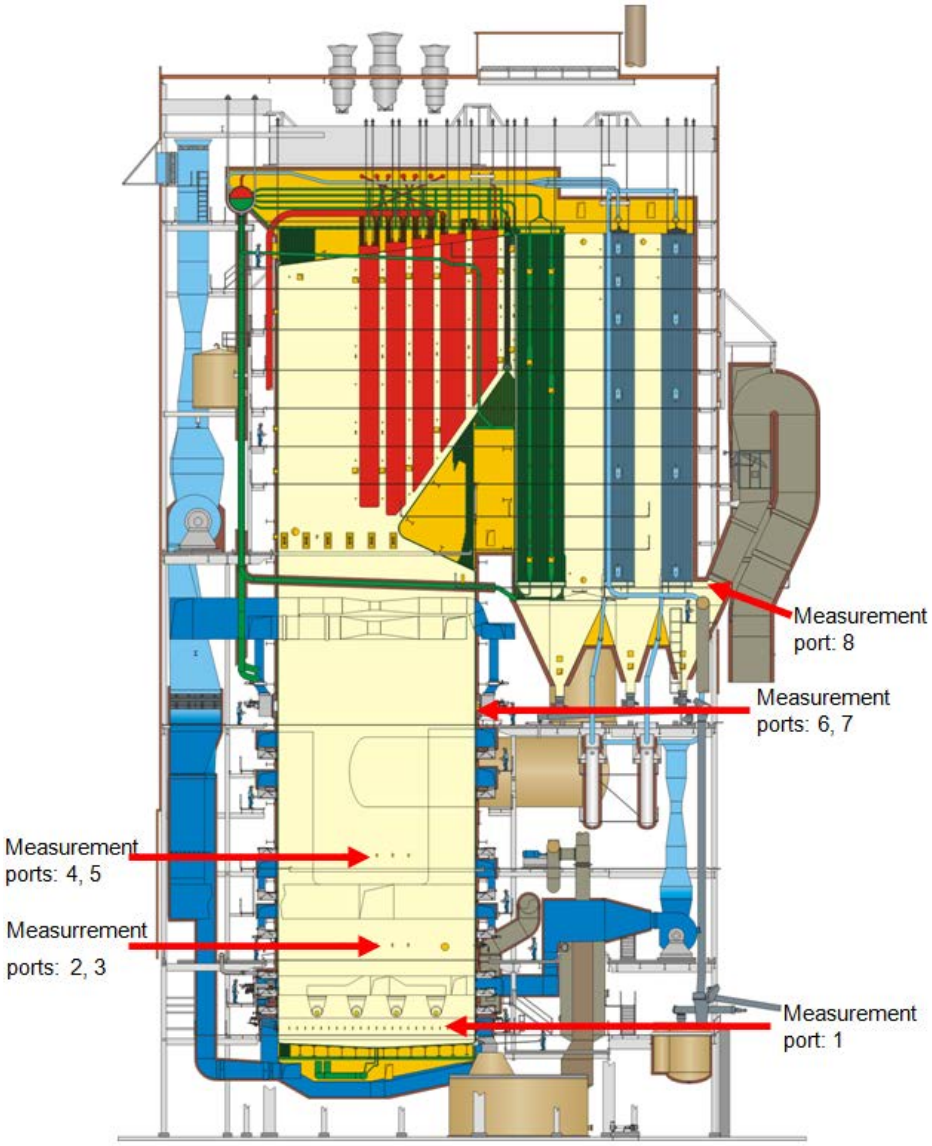
Probe in the camera opening





In-Furnace Gas Sampling Points





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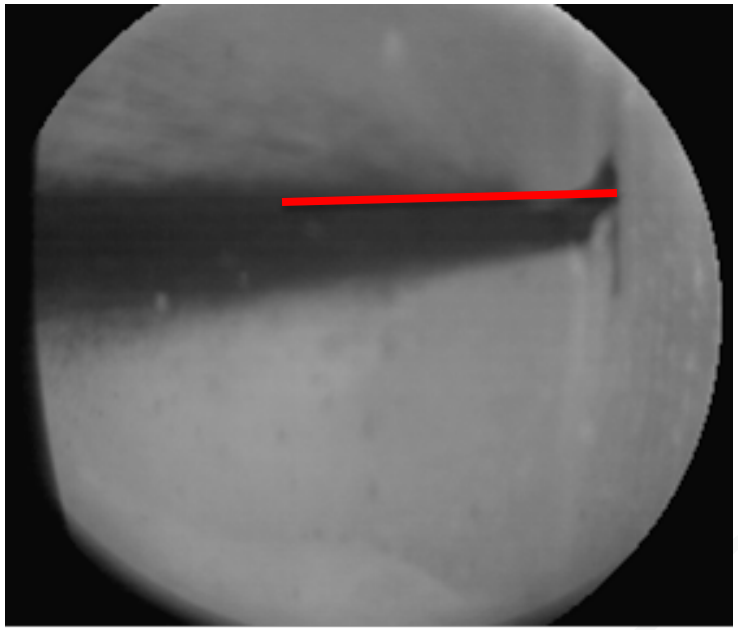
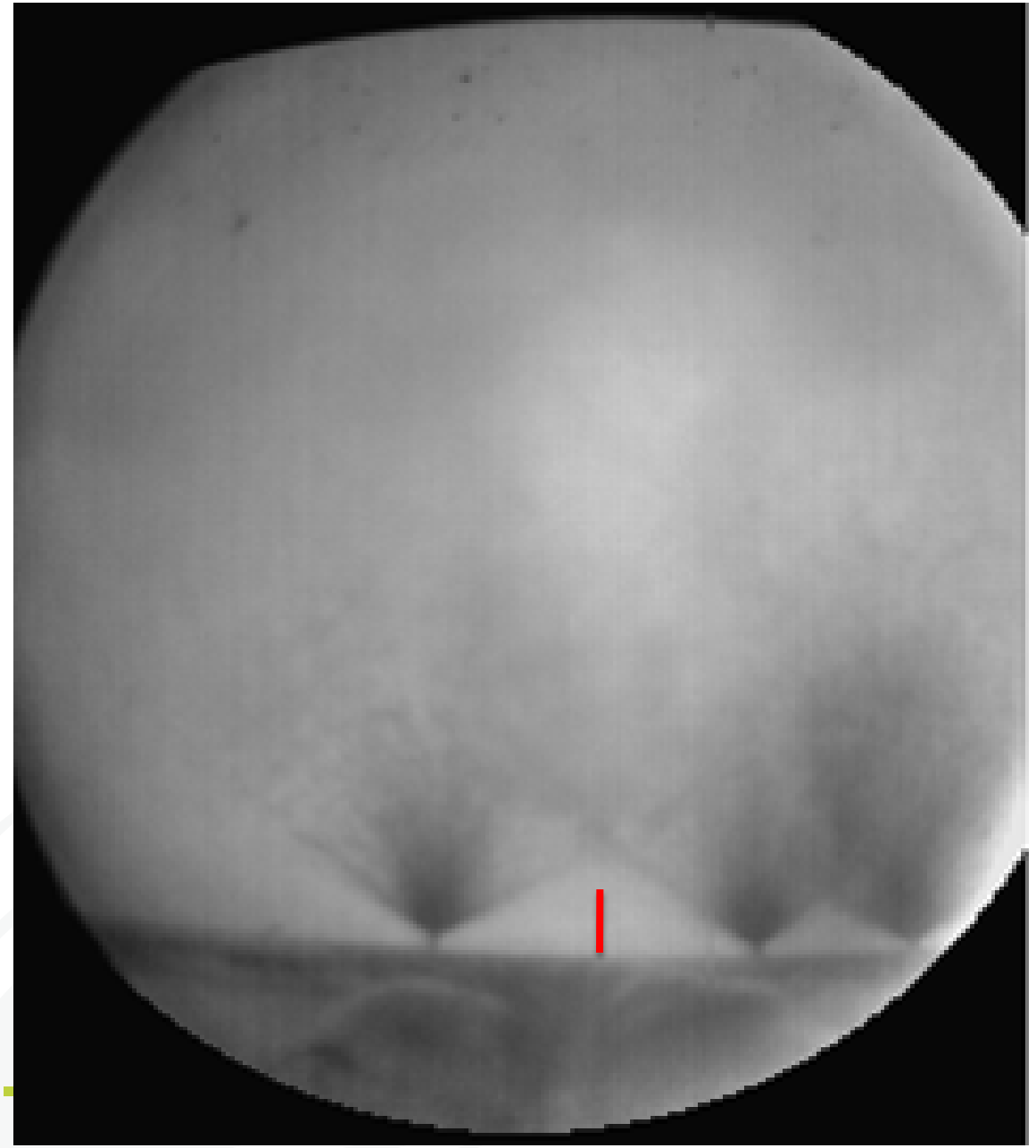
Furnace Camera (IR, 3,9 µm)

PYROINC 380

- Spectral Filter 3.9 µm
- Temp. Range 400-1500°C
- Temp. Resolution ≤ 1 K
- Field of View 67°x50°
- Diameter of Probe 104 mm
- IR -2D Array 384 x 288 Pixel
- Frame Rate 50 fps

Probe between the Liquor Guns



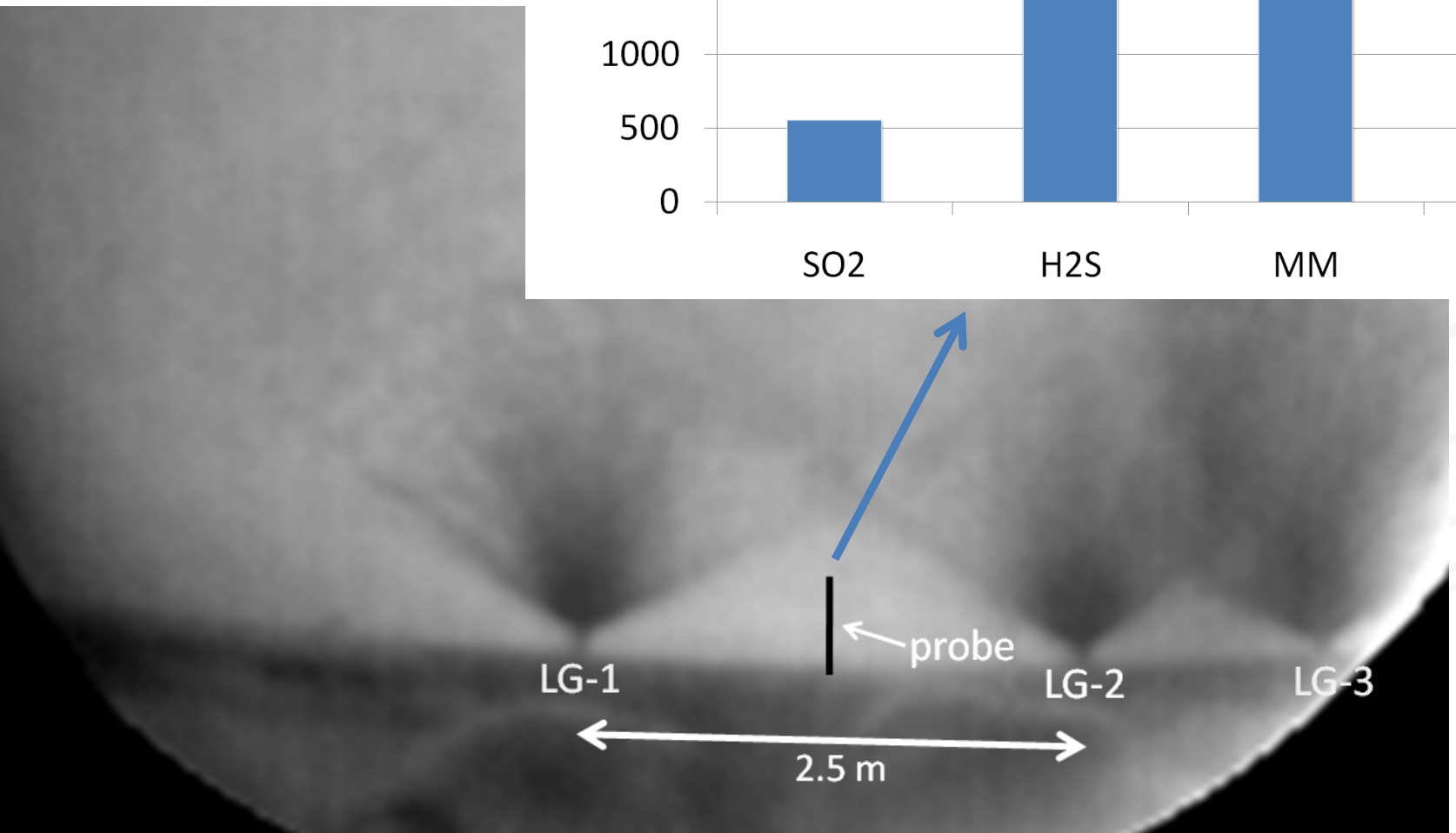


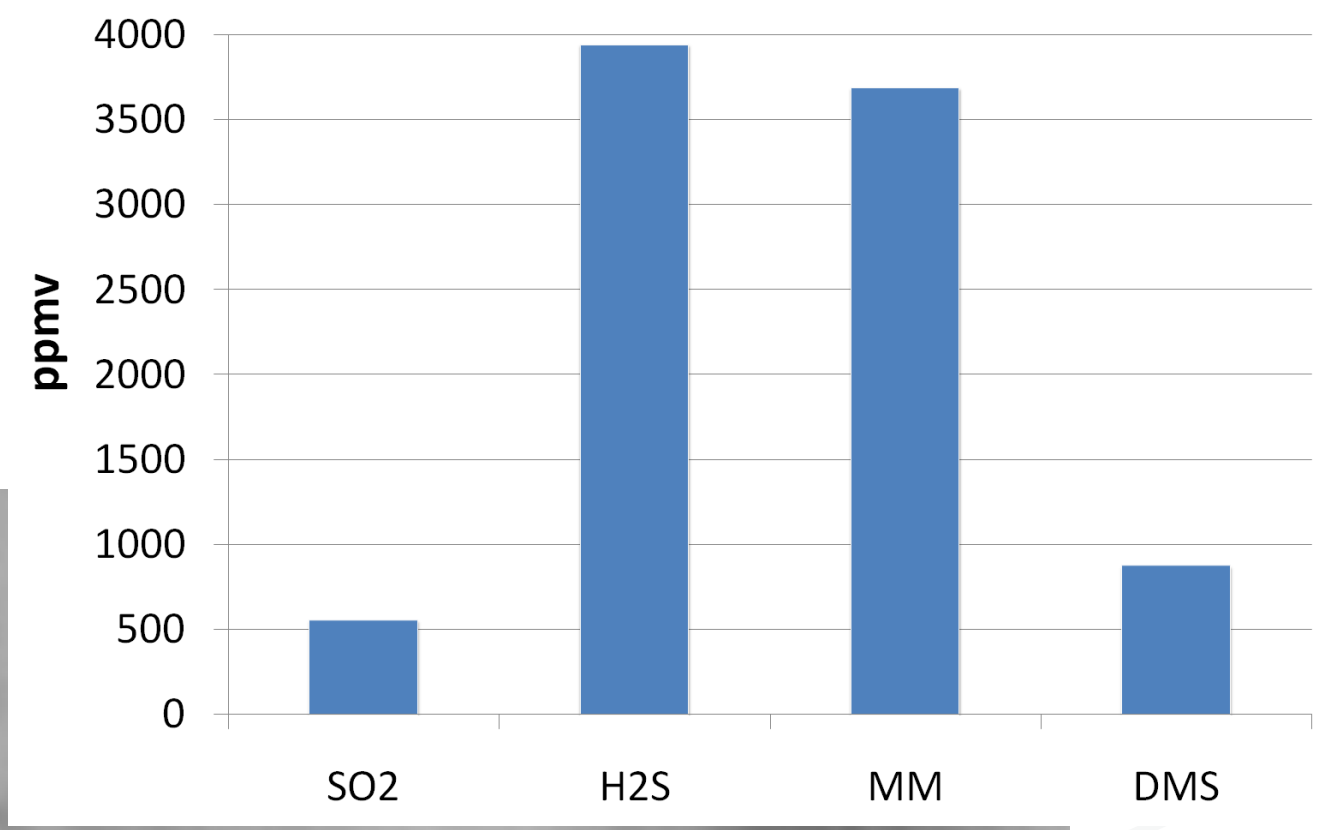
Results

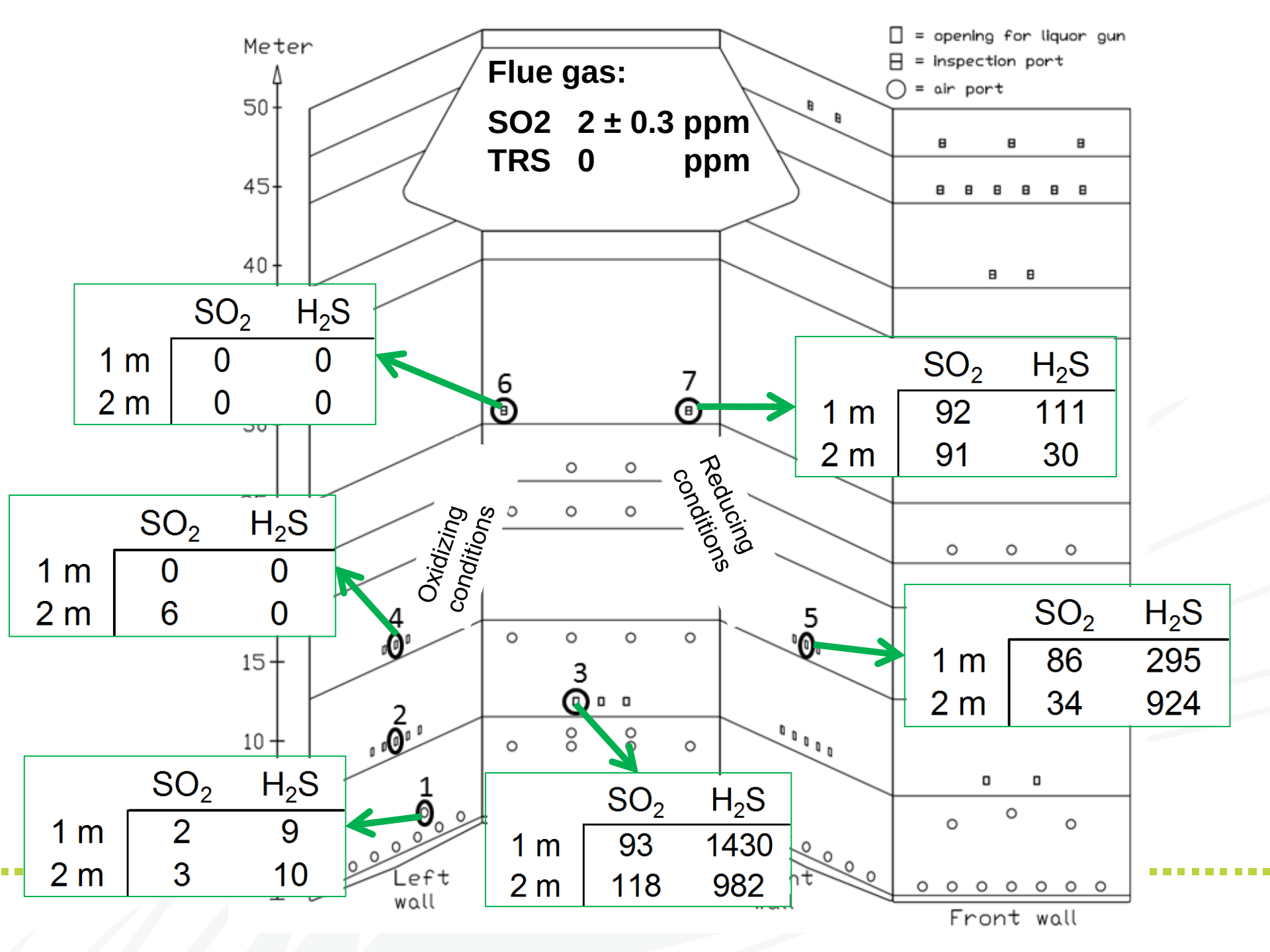
Sulfur species

Nitrogen species

Measurement between the liquor guns



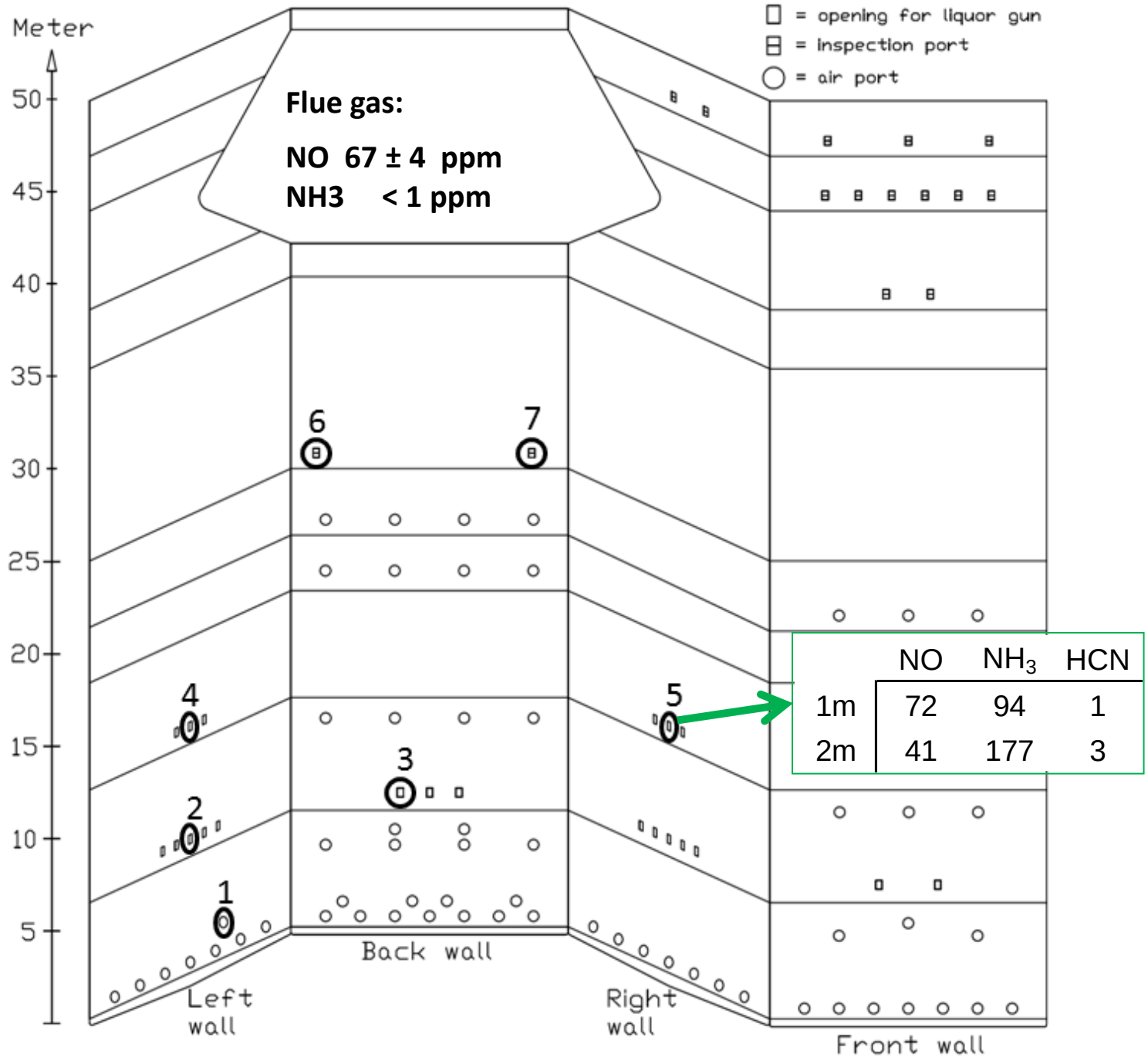


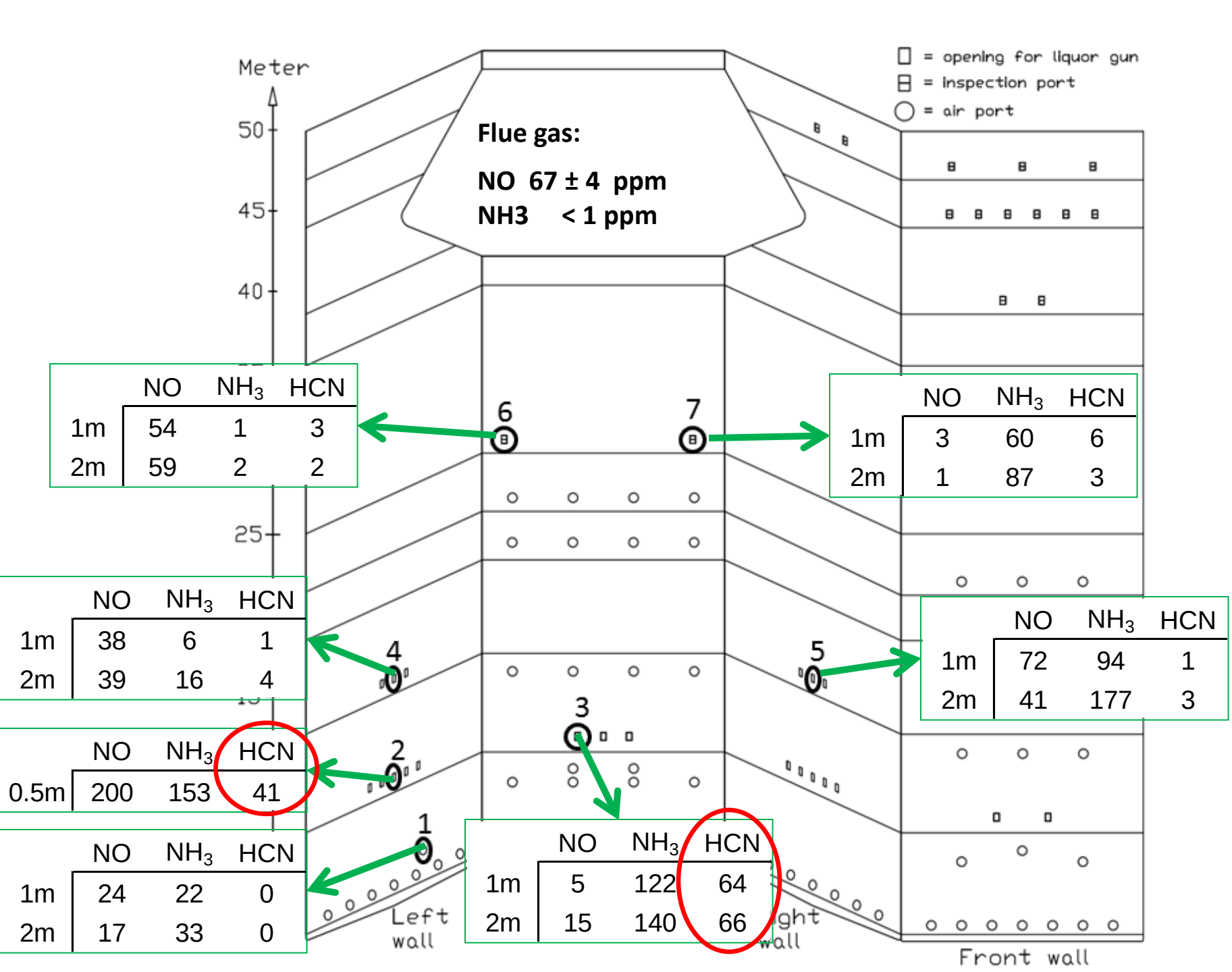

Meter
50
45
40
15
10
= opening for liquor gun
= inspection port
= air port
Flue gas:
SO2 2 ± 0.3 ppm
TRS 0 ppm
SO2 H2S
1 m 0 0
2 m 0 0
SO2 H2S
1 m 92 111
2 m 91 30
SO2 H2S
1 m 0 0
2 m 6 0
SO2 H2S
1 m 86 295
2 m 34 924
SO2 H2S
1 m 2 9
2 m 3 10
SO2 H2S
1 m 93 1430
2 m 118 982
Oxidizing conditions
Reducing conditions
1
2
3
4
5
6
7
Left wall
Front wall

Results

Sulfur species

Nitrogen species


Meter
50
45
40
35
30
25
20
15
10
5
= opening for liquor gun
= inspection port
= air port
Flue gas:
NO 67 ± 4 ppm
NH3 < 1 ppm
1
2
3
4
5
6
7
Back wall
Left wall
Right wall
Front wall
NO NH3 HCN
1m 72 94 1
2m 41 177 3



	NO	NH_3	HCN
1m	54	1	3
2m	59	2	2

	NO	NH_3	HCN
1m	3	60	6
2m	1	87	3

	NO	NH_3	HCN
1m	38	6	1
2m	39	16	4

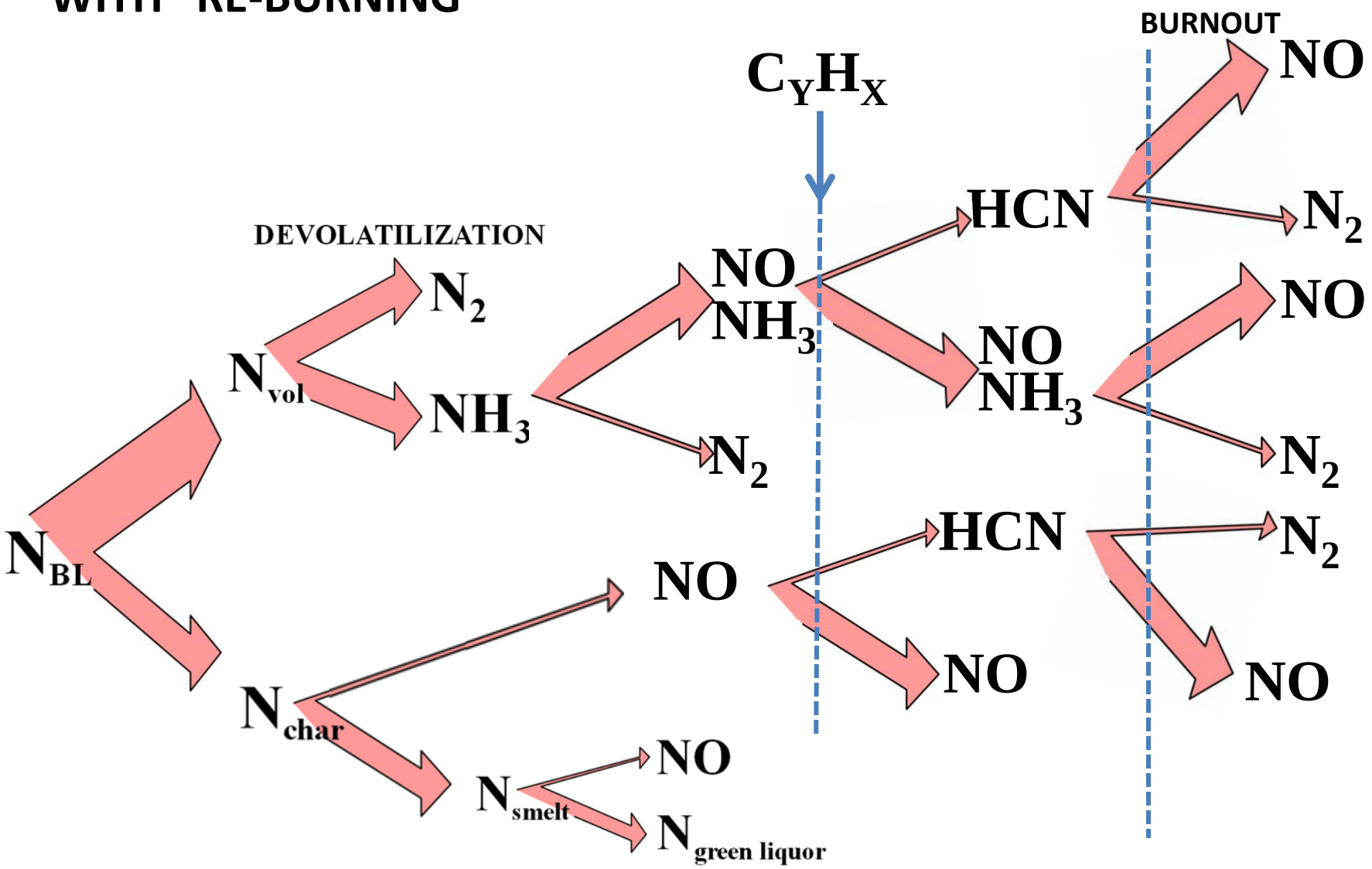
	NO	NH_3	HCN
1m	72	94	1
2m	41	177	3

	NO	NH_3	HCN
0.5m	200	153	41

	NO	NH_3	HCN
1m	24	22	0
2m	17	33	0

	NO	NH_3	HCN
1m	5	122	64
2m	15	140	66

MODIFIED BLACK LIQUOR NITROGEN REACTION ROUTES WITH ”RE-BURNING”



Aknowledgements