Characterisation of ash deposits generated co-firing coal and biomass blends under oxy-firing conditions

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Delivering Low Carbon Energy from Biomass Resources

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Oxy-combustor facility

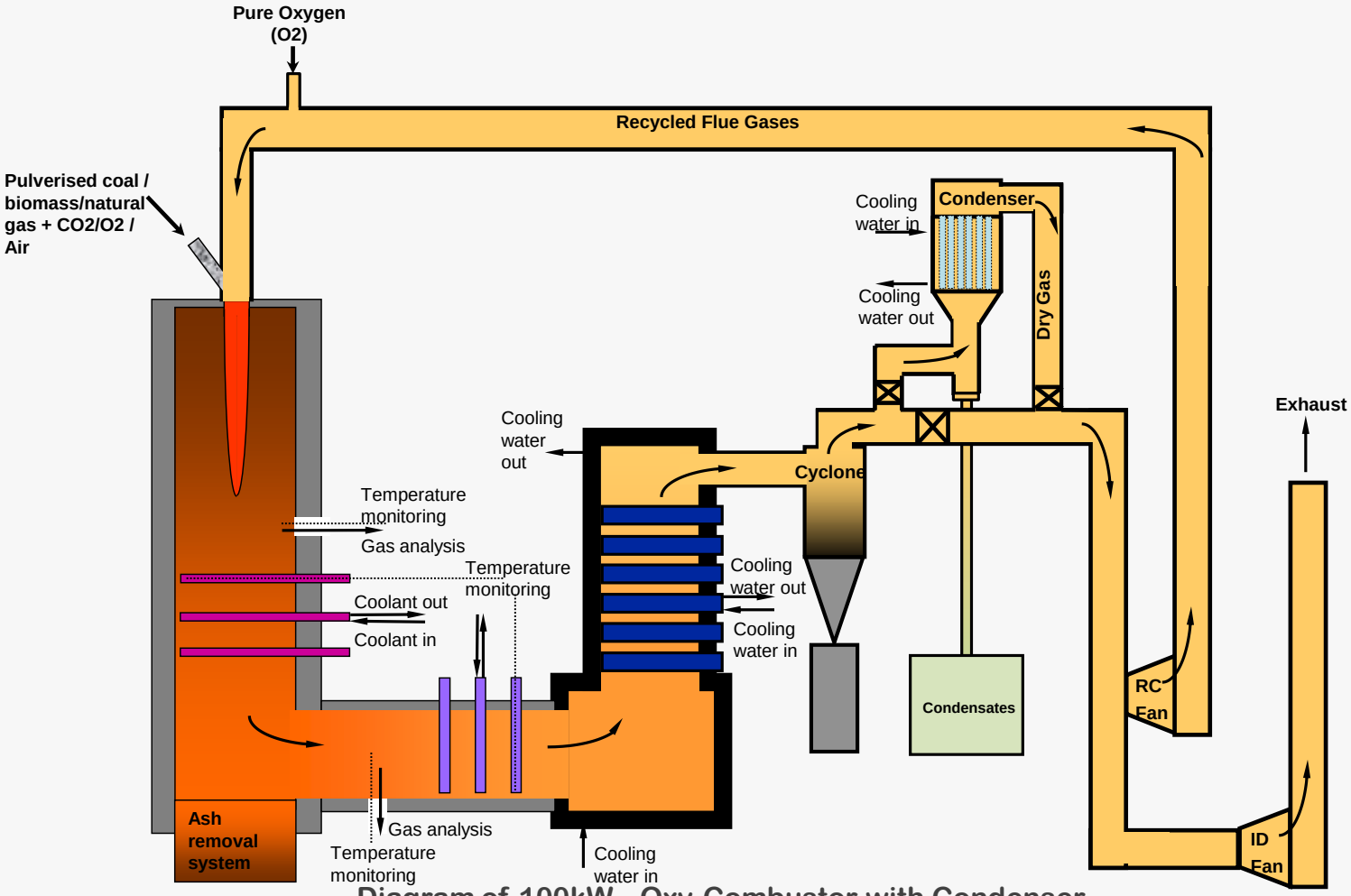
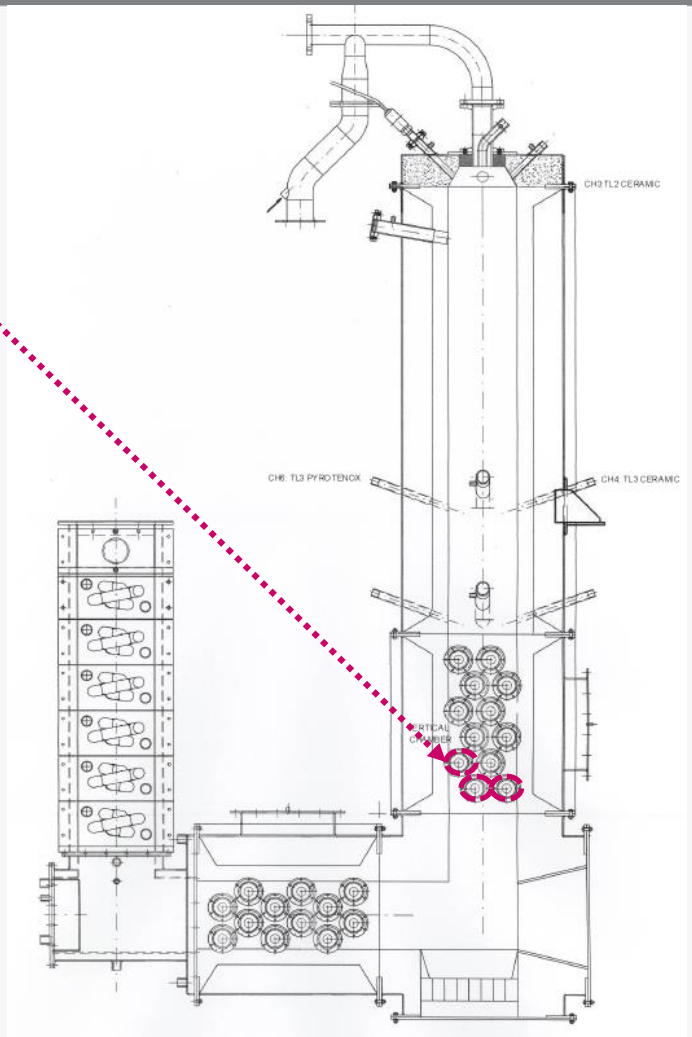


Diagram of 100kW$_{th}$ Oxy-Combustor with Condenser

Oxy-combustor facility

PROBES AND LOCATION



Retrofitting Process
LATEST MODIFICATIONS

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CONDENSER

New calibration model needed for the FTIR (Higher concentrations of CO_2 expected)

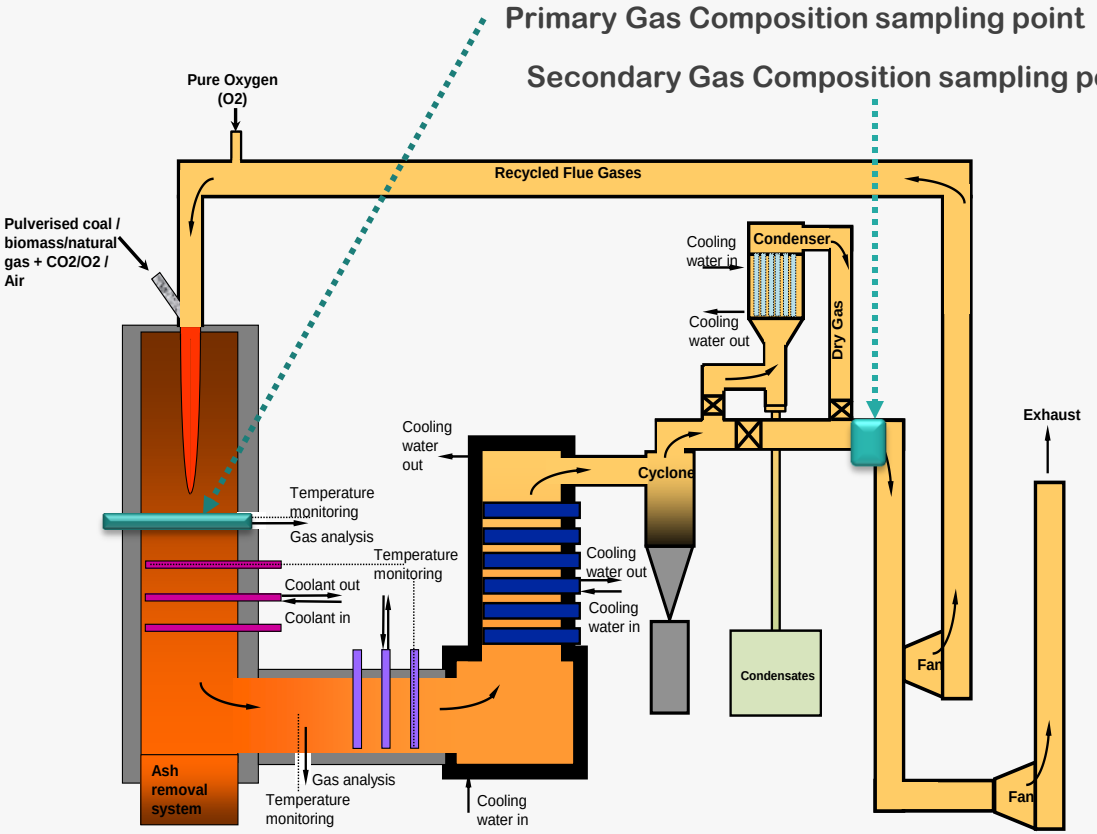

Diagram of 100kWth Oxy-Combustor with Condenser

Retrofitting Process
LATEST MODIFICATIONS

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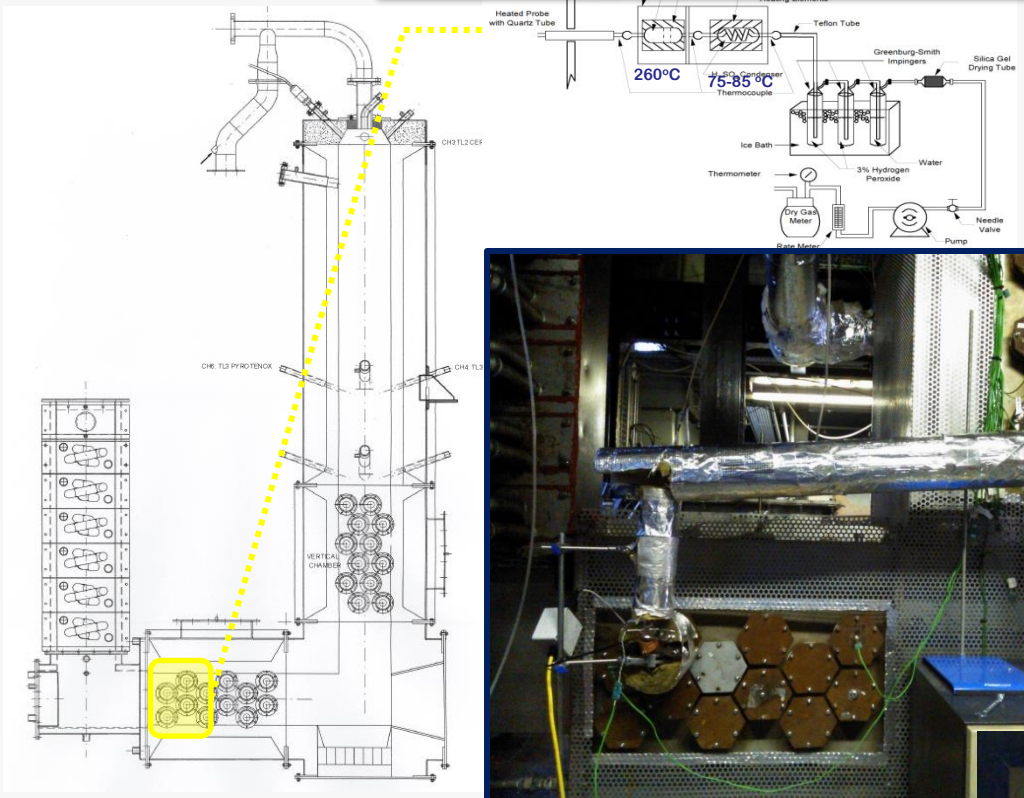
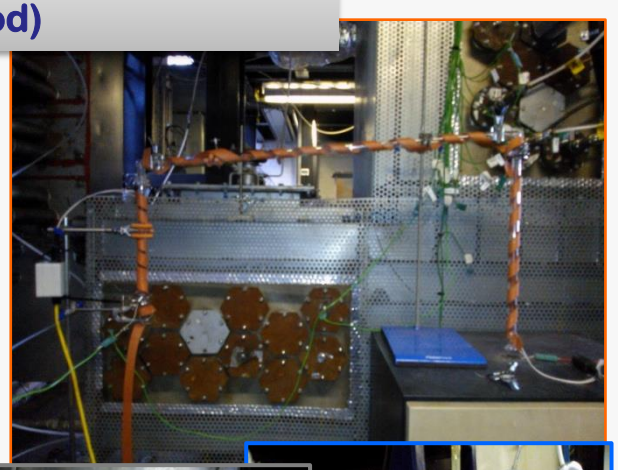
SO_3 AND SULFATES MEASUREMENT
(Controlled Condensation Method)



Location of the sampling point



Experimental conditions

- Type of fuel: El Cerrejon Coal 13.5kg/h
  75% El Cerrejon -25% CCP 15kg/h
  50% El Cerrejon -50% CCP 16.7kg/h
  Cereal co –product 22kg/h
- Percentage of Recycled Flue Gas :60-65%
- Types of Recycled Flue Gas
  - Wet- Hot Recirculation (After Particle Removal)
  - Dry – Cool Recirculation (After Particle, Condenser)
- Oxygen Injection
  - Primary O_2 (Fuel carrier draught): Not Used
  - Secondary O_2: 34-38% in gas supplied

Experimental conditions
FUEL ANALYSIS

	El Cerrejon coal	Cereal co-product
Proximate analysis (% (wt) as received)		
Moisture	5.80	8.10
Volatile matter	34.80	70.80
Ash	8.60	4.20
Calorific value, (MJ/kg)		
Gross calorific value	27.85	17.61
Net calorific value	27.12	16.34
Ultimate analysis (% (wt) as received)		
Carbon	69.2	43.30
Hydrogen	4.40	5.80
Nitrogen	1.42	2.70
Chlorine	0.02	0.17
Sulfur	0.58	0.16
Oxygen	9.98	35.57
Ash analysis (% (wt))		
SiO_2	60.69	44.36
Al_2O_3	22.01	2.79
Fe_2O_3	7.43	2.47
TiO_2	0.92	0.12
CaO	2.27	7.78
MgO	2.90	3.96
Na_2O	1.06	0.36
K_2O	2.32	24.72
Mn_3O_4	0.06	0.10
P_2O_5	0.21	12.04
SO_3	-	-
BaO	0.11	0.05

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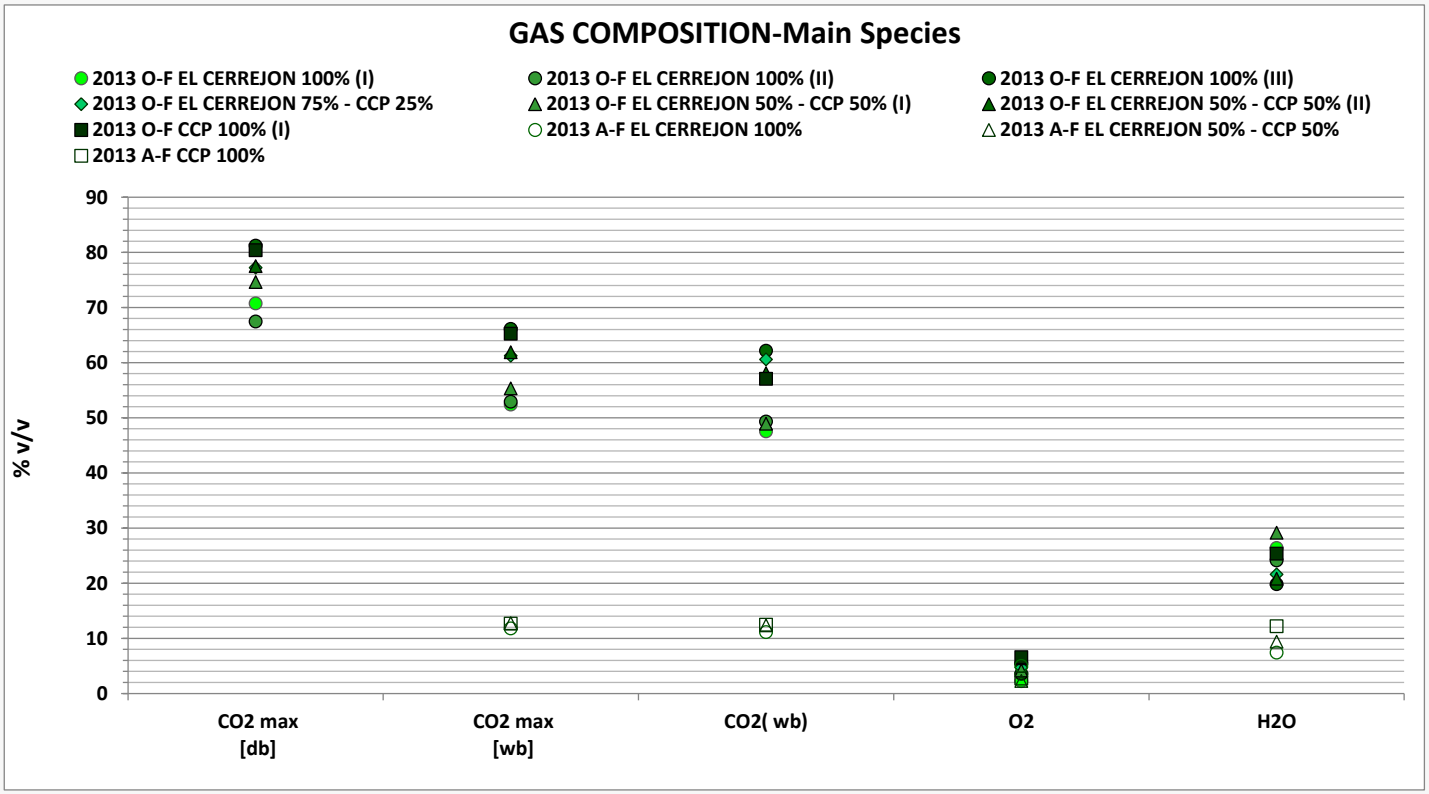
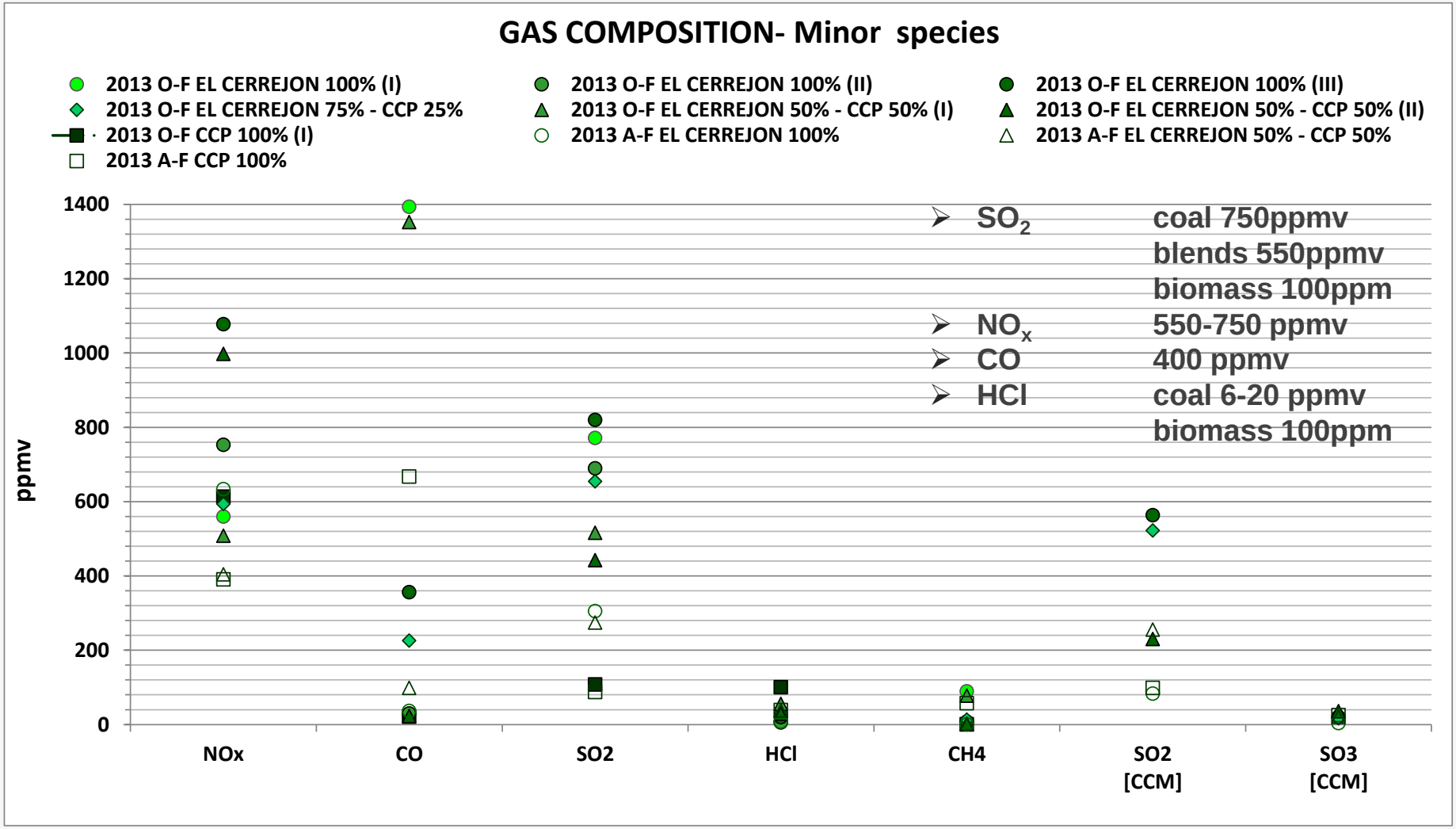
Experimental Results
GAS COMPOSITION

- Maximum CO_2 : 57-62% wet basis [80-81% (d. b.)]
- H_2O ~ 20-29% (v/v)
- O_2~ 4.3% (v/v)



Experimental Results
GAS COMPOSITION



Experimental Results
SO3 & SULFATES

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	SO_2_FTIR (ppmv)	SO_2_CCM (ppmv)	$(SO_3+SO_4^{2-})$_CCM (ppmv)	$(SO_3+SO_4^{2-})/SO_2$ (%)
Air-firing El Cerrejon	305.2	83.5	3.0	3.6
Air-firing 50%EC-50%CCP	274.3	245.8	16.6	6.7
Air-firing CCP	87.6	98.9	20.8	21.0
Oxy-firing El Cerrejon	819.6	566.8	16.9	3.0
Oxy-firing 75%EC-25%CCP	654.3	525.2	13.8	2.6
Oxy-firing 50%EC-50%CCP	442.2	231.4	29.5	12.7

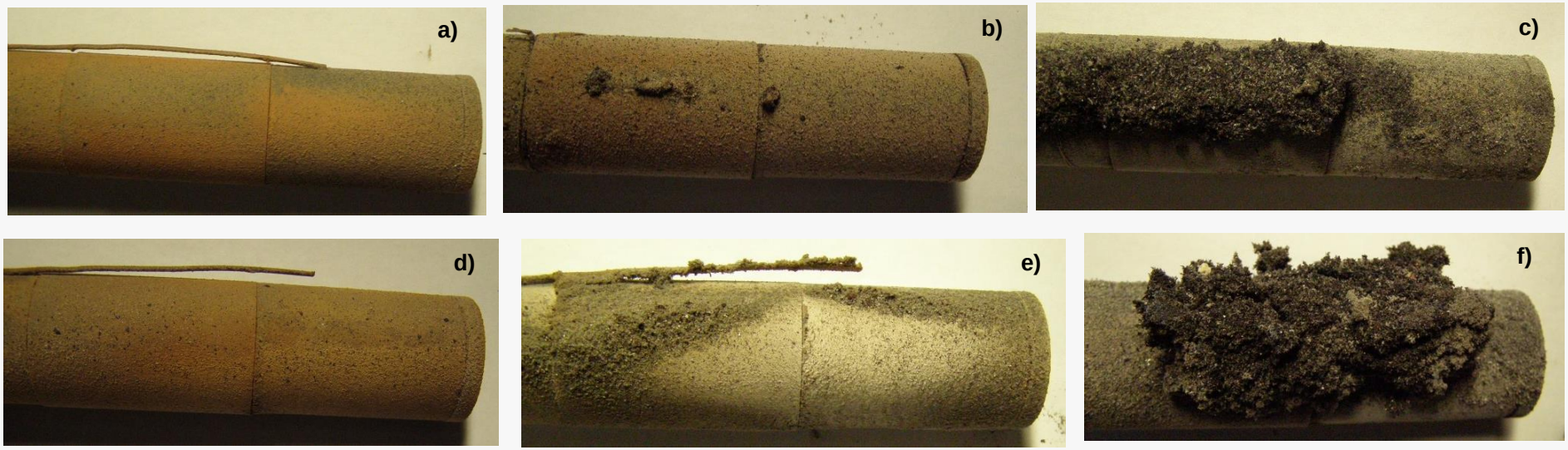
Effect of fuel: $SO_3+SO_4^{2-}$ levels rising as the share of CCP increases

- Alkalis reaction with SO_3 to generate sulfates
- SO_2 to SO_3 promoted by alkalis

Effect of firing mode: $SO_3+SO_4^{2-}$ levels in oxy-firing higher than in air-firing

Experimental Results
ASH DEPOSITS

The structure of the deposit is more fibrous and porous using 100% CCP than when oxy-firing 100% El Cerrejon coal or the coal-biomass blends. No significant difference in the aspect of the deposits can be observed comparing the cases under oxy and air-firing conditions.



a) Air- firing El Cerrejon b) Air-firing 50%EC-50%CCP c) Air-firing CCP
d) Oxy- firing El Cerrejon e) Oxy-firing 50%EC-50%CCP f) Oxy-firing CCP

Experimental Results

ASH DEPOSITS

El Cerrejon coal & CCP

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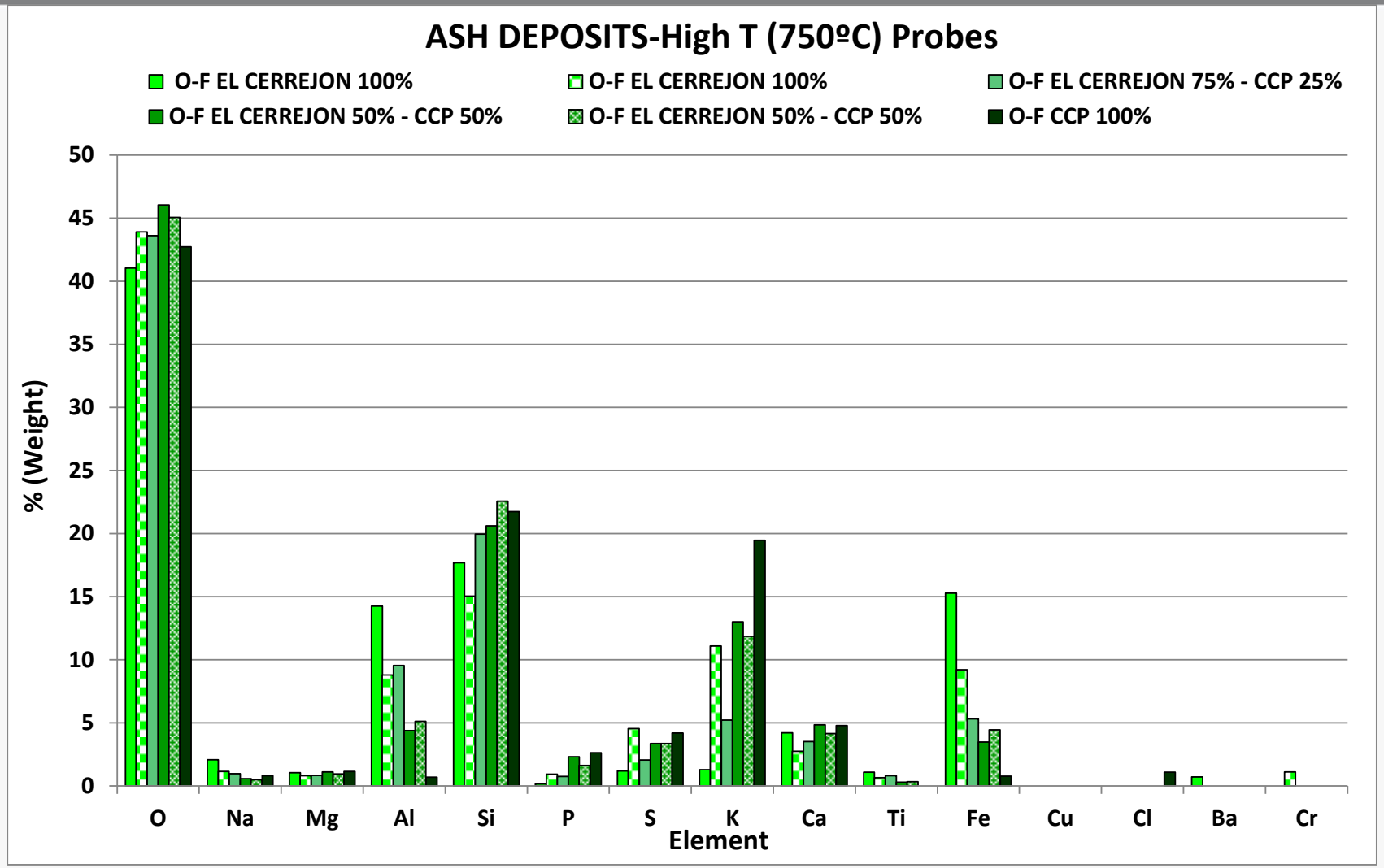

Key findings- Experimental

- Gas composition
  - CO_2 >80% (db) for pure coal and pure biomass
  - H_2O 20-29%, even with dry recycle
  - NO_x 550-750ppmv
  - SO_2 100-750ppmv
  - HCl 8-100ppmv
  - $SO_3+SO_4^{2-}$ 14-30ppmv

Clear increase in $(SO_3+SO_4^{2-})/SO_2$ ratio when ↑%CCP

- Ash deposits
  - Markedly fibrous and cohesive for high shares of CCP
  - Similar S levels for pure coal and biomass (K_2SO_4 generation)
  - Chloride only observed in ash deposits from pure CCP

Operational issues associated to the use of Biomass

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- **Difficulty to control the %RFG when using coal-biomass blends and pure biomass (liquid accumulation in the condenser)**
- **The $\eta_{condenser}$ dropped sharply after two hours of operation**
- **Dry recycle used from the start of the tests with 100% biomass (otherwise minimal efficacy)**
- Some air ingress into the process through the deposit probes (due to cooling air)
- Appropriate maintenance of heat flux sensor
- Decrease of air ingress from 10% to 5% (improved sealing of the facility and operation at slightly positive pressure)

Future challenges

- **Use of other fuels:**
  - *Coal with higher S levels: effect on SO_x generation*
  - *Biomass with higher Na contents: effect on ash deposits characteristics*

- **Further investigation on SO_3/SO_2 ratios using high shares of biomass**
  Applying identical procedure to EPA-Method 8A (avoiding sulfates interferences)

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