Investigation of Oxy-Coal Combustion in Semi-technical Test Facilities

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Overview

Results from 20 kW once-through furnace to investigate:

- Emission behaviour during un-staged combustion.
- NO_x formation mechanism in fuel-rich condition.
- NO_x reduction potential during staged-combustion.
- Fate of recycled NO_x.

Up-date on 500 kW furnace with flue-gas re-circulation on:

- Operational procedures including, start-up and shut-down.
- Switching from air to oxy-coal combustion.

Set-up and description of 20 kW once through furnace

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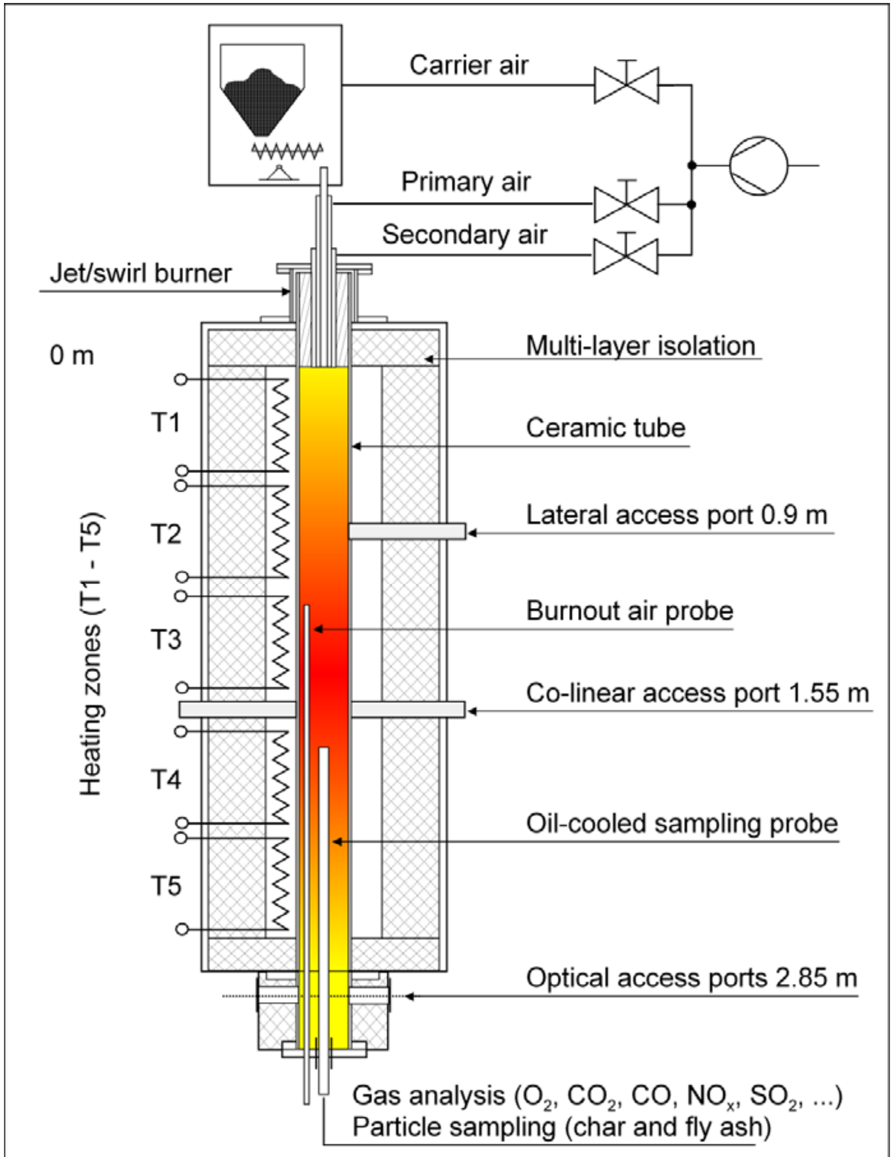
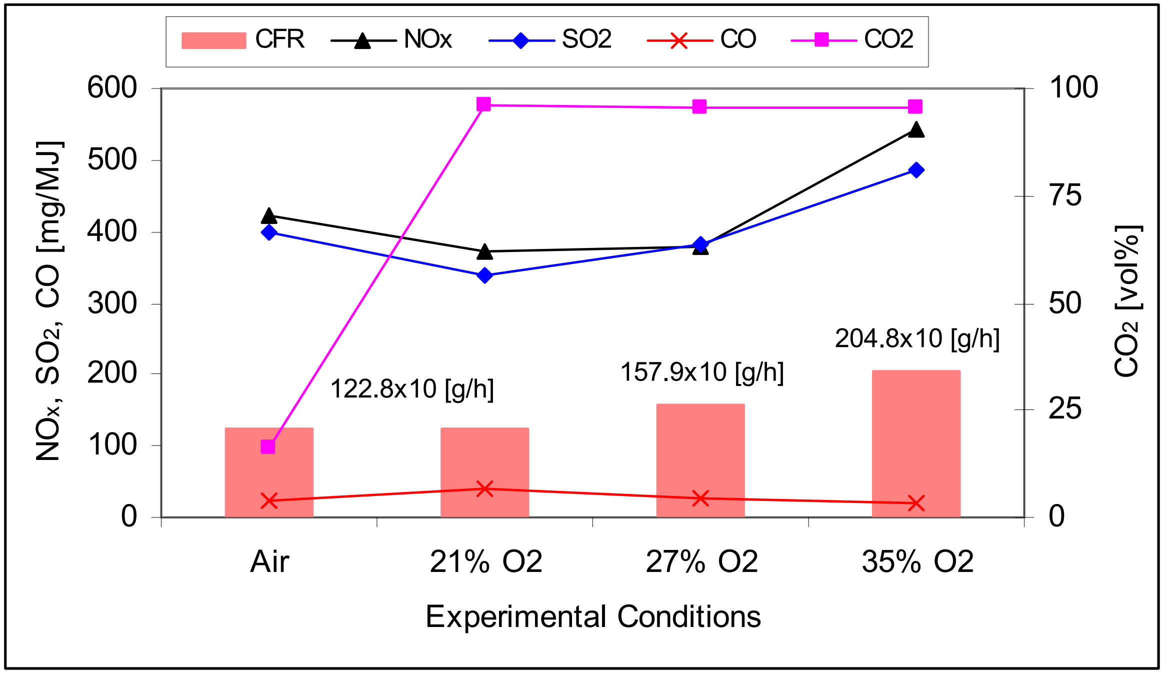


Coals Used	Medium vol bituminous coal Klein Kopje	High volatile Lausitz Brown Coal
LHV (kJ/kg)	24,932	21,412
Moisture [%, ar]	3.60	10.20
Ash [%, wf]	19.29	5.46
Volatile [%, waf]	27.76	57.36
Fixed Carbon [%, waf]	72.24	42.64
Carbon [%, waf]	83.93	66.78
Hydrogen [%,waf]	4.50	5.26
Nitrogen [%,waf]	1.67	0.65
Sulphur [%,waf]	0.36	0.72
Oxygen [by diff]	9.54	26.59

Experiment Conditions	**Air**	**O_2/CO_2 combustion**		
		21% O_2	**27% O_2**	**35% O_2**
Overall Stoichiometry	1.15	1.15	1.15	1.15
O_2 excess [vol%]	2.74	2.74	3.54	4.56
Wall Temperature [°C]	1300	1300	1300	1300

Emission Behaviour during un-staged combustion

Klein Kopje Coal



- Need for expressing emission in a comparable way.
- Minimum NO_x emission rate during oxy-coal combustion with O_2 concentration between 21-27% vol.
- Fuel NO_x emission increases with increase in O_2 partial pressure.
- **Comparison with actual process: mass of emission is much lower during oxy-coal combustion when recirculation is considered.**

NO_x reduction potential during staged combustion

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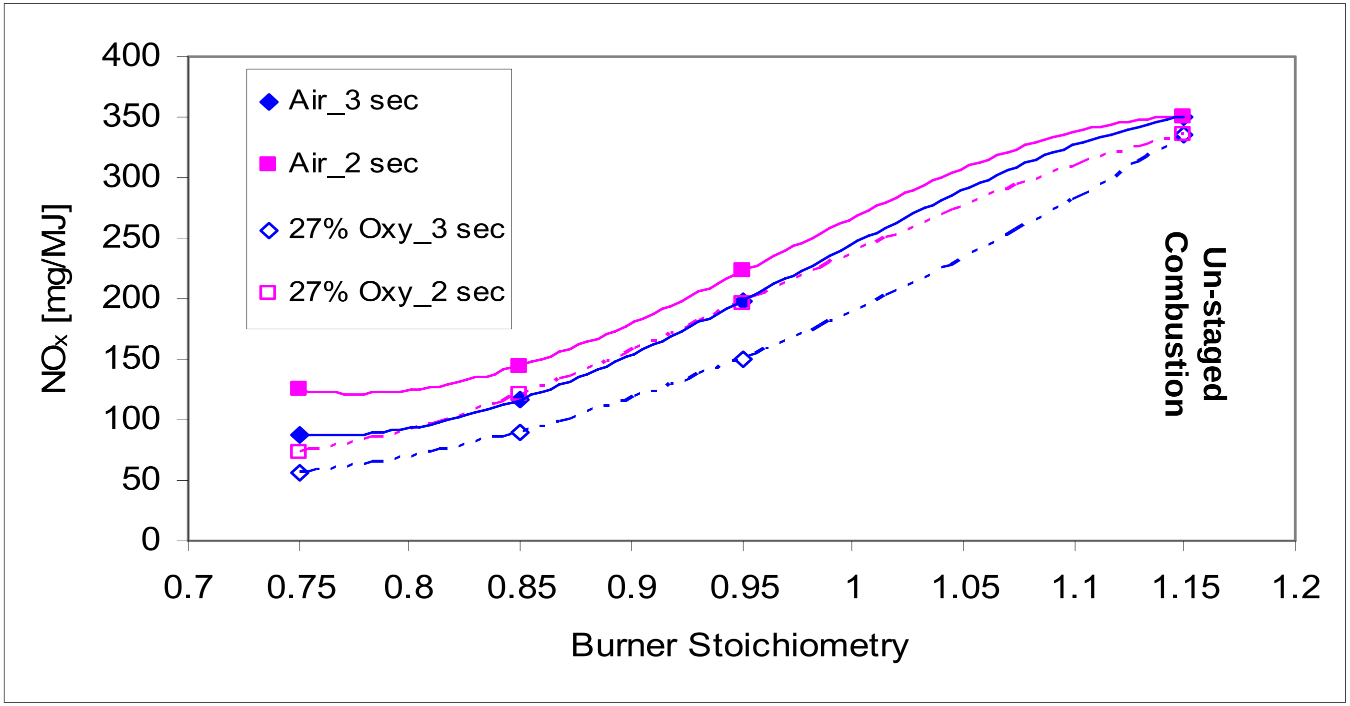
Klein Kopje Coal



Parameters	Optimum	Effect
Burner Stoichiometry	0.75-0.85	Oxygen deficiency, encouraging formation of N_2
Residence time in reduction zone	2-3 seconds	Longer time available for conversion of NO_x precursors to N_2
Temperature		Shift of coal-N towards gas phase

NO_x formation mechanism- Lausitz Coal

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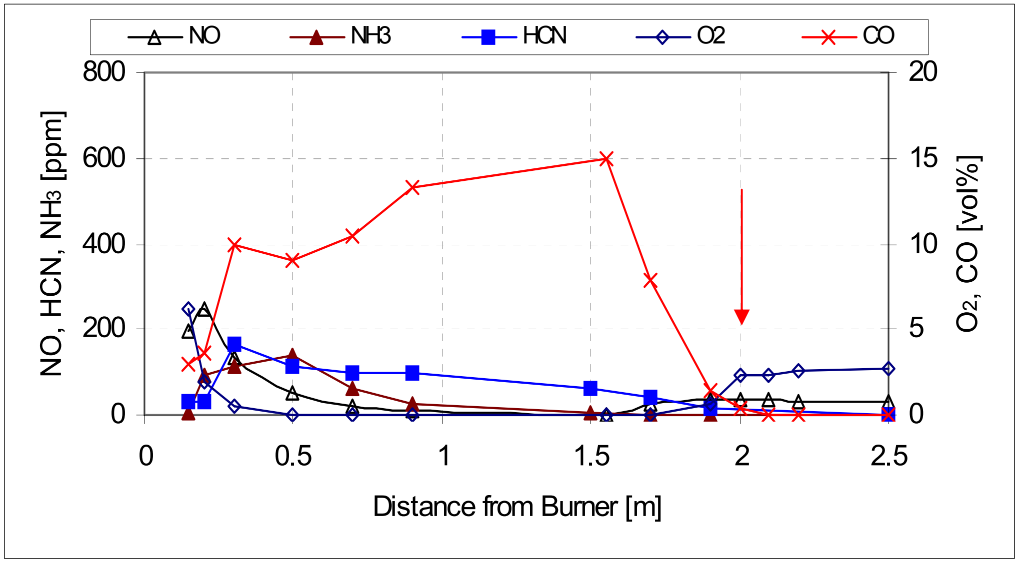
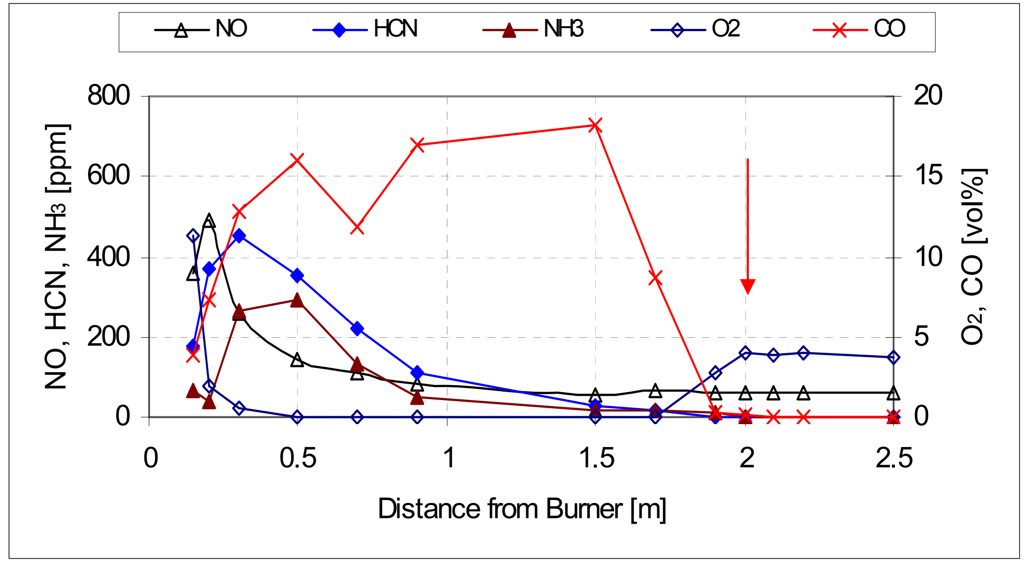
Air Combustion

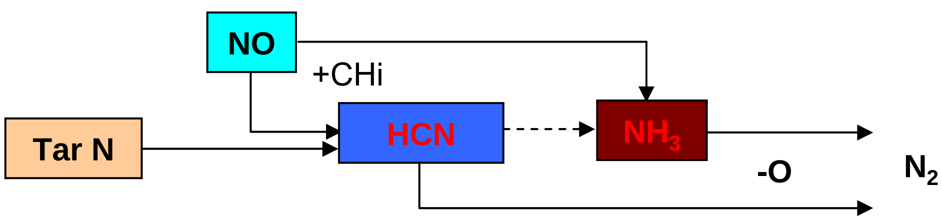


Oxy-Coal Combustion (27% O_2)



Overall Stoichiometry = 1.15, Burner Stoichiometry = 0.75, Residence time in reduction zone ~ 3 seconds

Generalised NO_x Reduction path:



Like in conventional air-combustion, formation of NO_x precursors HCN and NH_3 is dependant on coal rank: medium volatile bituminous coal, Klein Kopje produces only HCN

Fate of recycled NO-Analysis Approach

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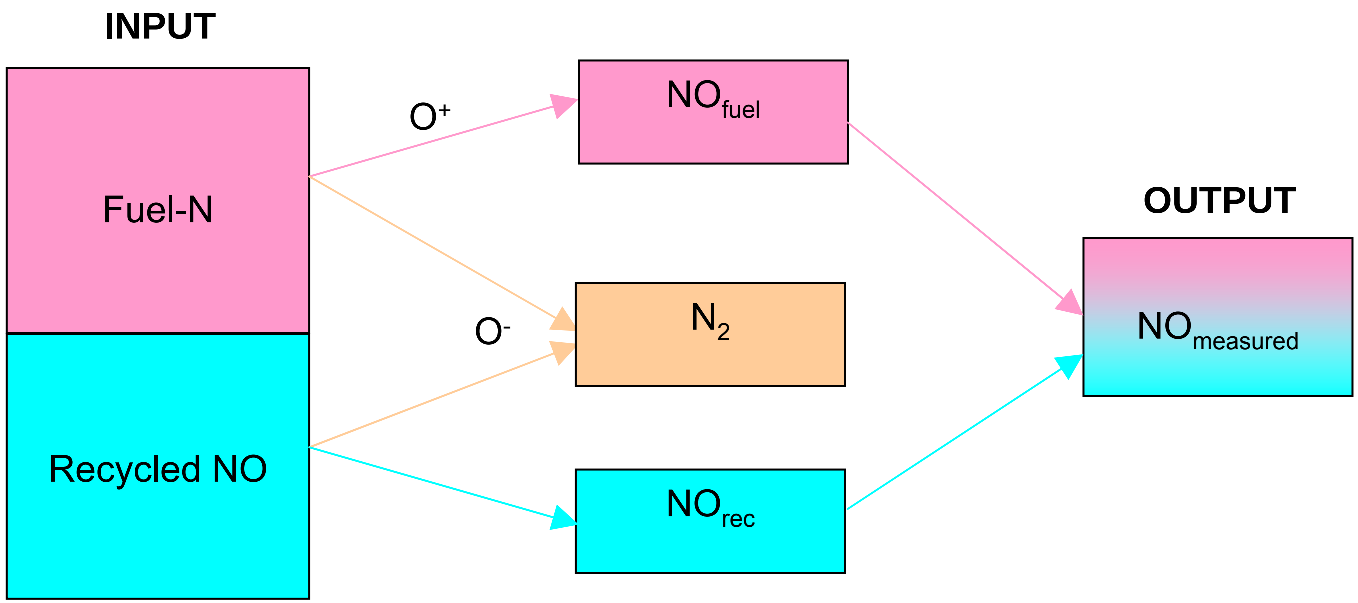

$$NO_{rec} = NO_{measured} - NO_{fuel}$$

$$\text{Reduction of Recycled NO [\%]} = \left[\frac{NO_{inj} - NO_{rec}}{NO_{inj}} \right] X\,100$$

NO_{inj}= Recycled NO

Fate of recycled NO_x

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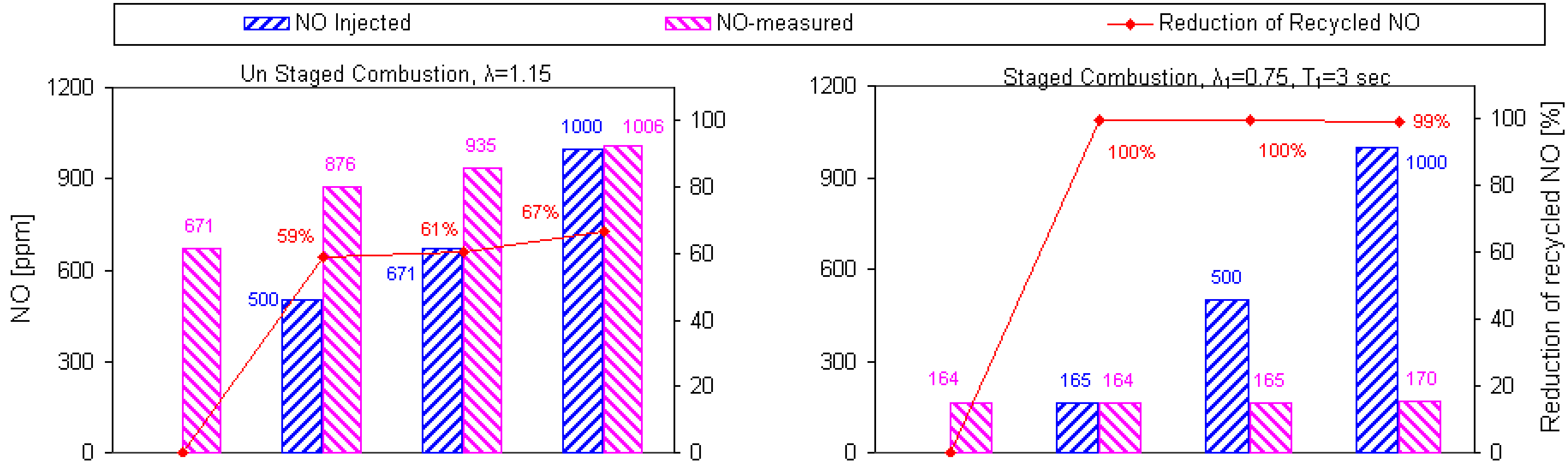

Medium Volatile Bituminous Coal, Klein Kopje

- Stable NO emission achieved at ~1000 ppm during un-staged combustion (much higher emission than initial emission of 671 ppm)
- Stable NO emission achieved at 164 ppm during staged combustion with burner stoichiometry of 0.75 (emission without injection of NO=emission with injection of NO)

Fate of recycled NO - Summary

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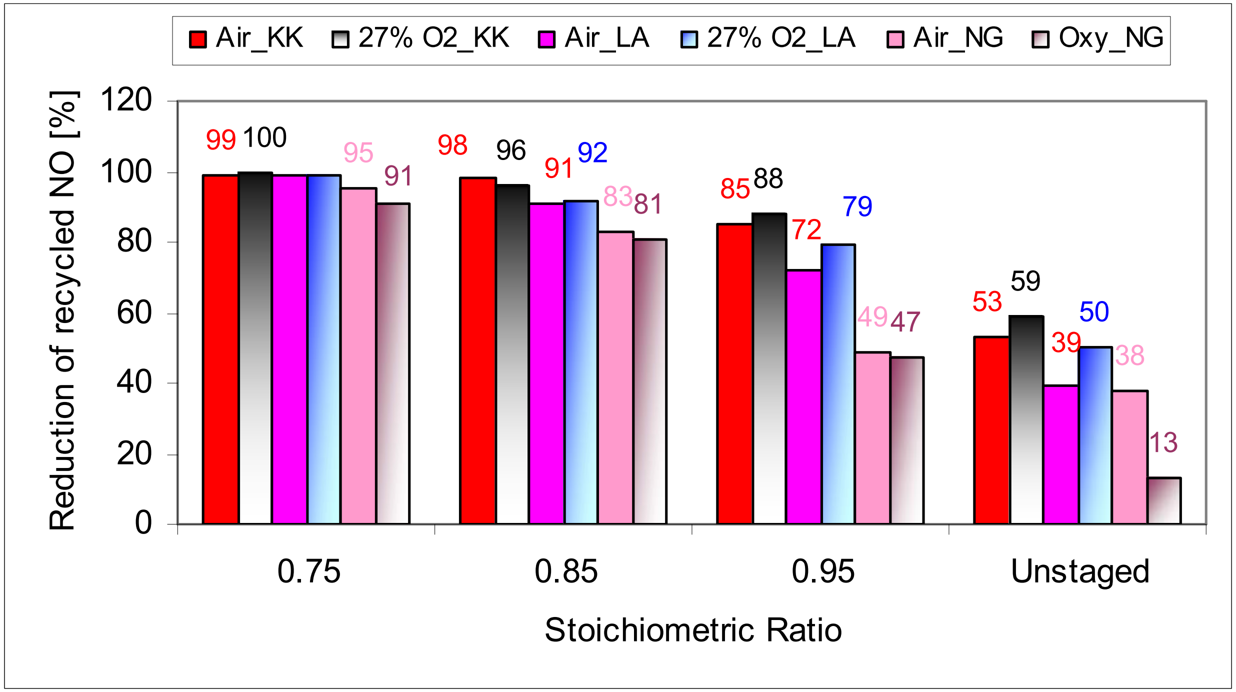

- Reduction dependant on combustion mode (burner stoichiometry and residence time in reduction zone.
- Generally higher reduction for oxy-coal combustion.
- For the coals investigated: for a particular combustion condition, percentage reduction during oxy-coal combustion is almost similar.
- **Combustion modification can take care of recycled NO_x accumulation.**

Conclusions from 20 kW furnace

- NO_x emission rate is lower during oxy-coal combustion with oxygen partial pressure between 21-27% (un-staged combustion).
- Oxidant staging is applicable for oxy-coal combustion.
- Path of fuel NO_x formation during oxy-coal combustion is similar to well established air-blown combustion route.
- Recycled NO_x can be reduced by combustion modification, with ~60% reduction during un-staged combustion and ~100% during staged combustion (λ_1=0.75 and T_1=3 sec) for all coals tested.
- CO in the near burner region is higher during oxy-coal combustion indicating enhancement of water-shift and CO_2 shift reactions.

500 kW test facility; oxy-fuel combustion with FGR

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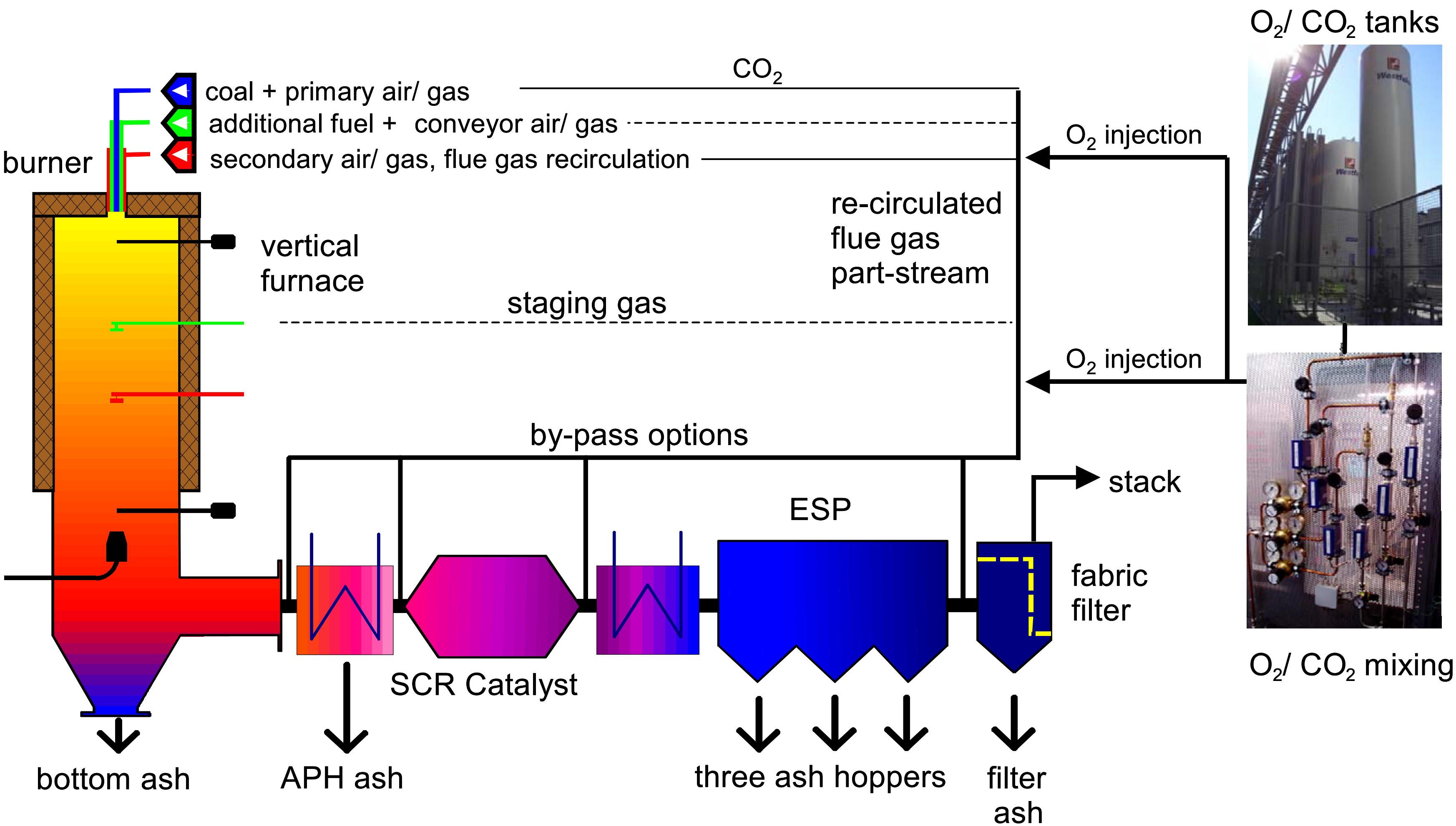

Switch from air to oxy-coal combustion

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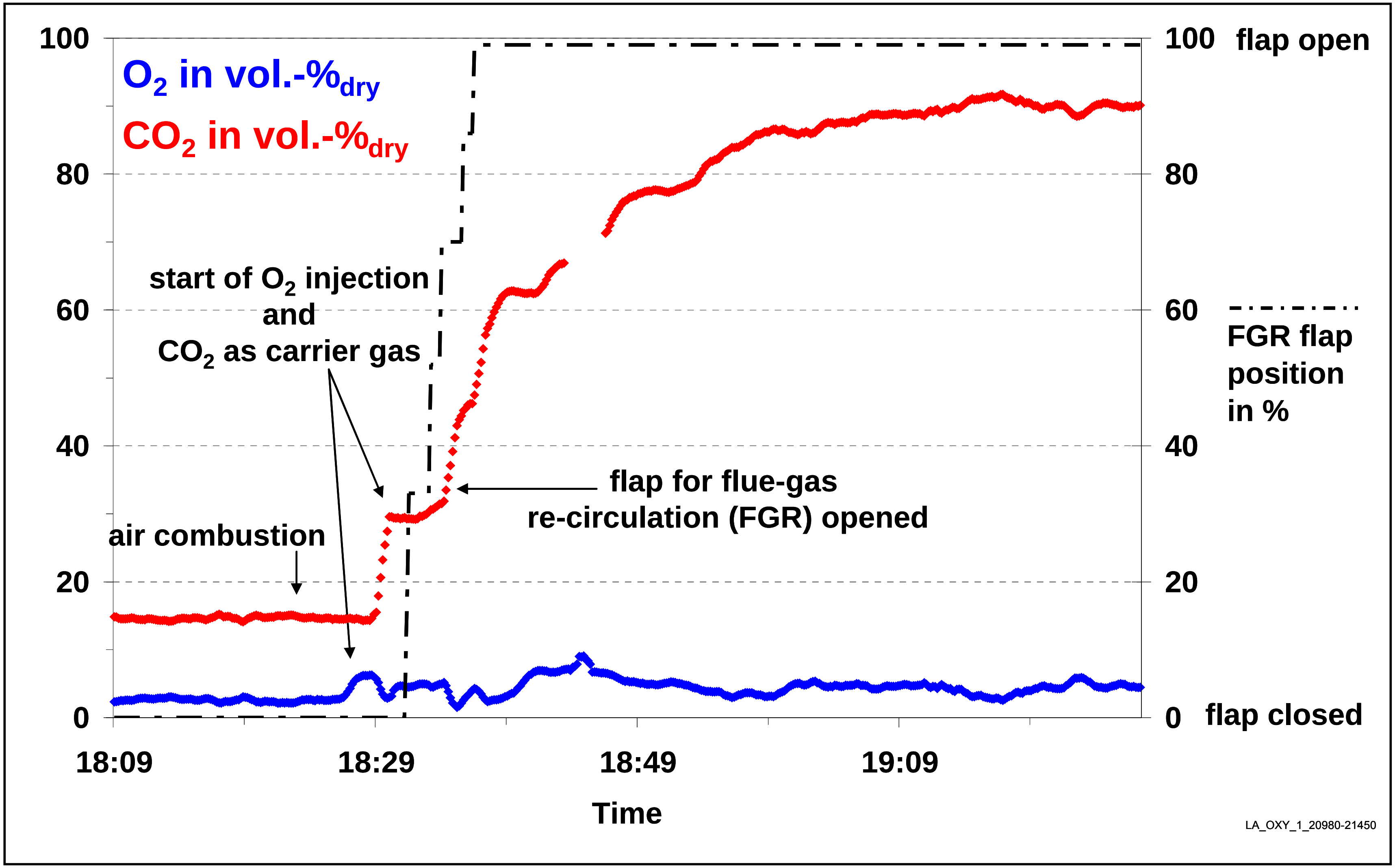

Conclusions from 500 kW furnace

- Operation under oxy-coal combustion with different ranks of coals achieved successfully.
- High CO_2 concentration achievable (~95% dry).
- Switching from air to oxy-fuel combustion, achievable in short time interval (~30 minutes).

Future Investigations

- Establish safe operational handling procedures.
- Investigate combustion characteristics like flame temperature, emission formations etc and validate with simulation.
- Investigate slagging, fouling and corrosion behaviour during oxy-coal combustion.
- Establish fate of recycled SO_2 and determine sulphur containing corrosive compounds like H_2S.
- Design and testing of a low NO_x oxy-coal burner.