INFUB - 11th European Conference on Industrial Furnaces and Boilers, INFUB-11

Oxy-fuel burner investigations for CO2 capture in cement plants

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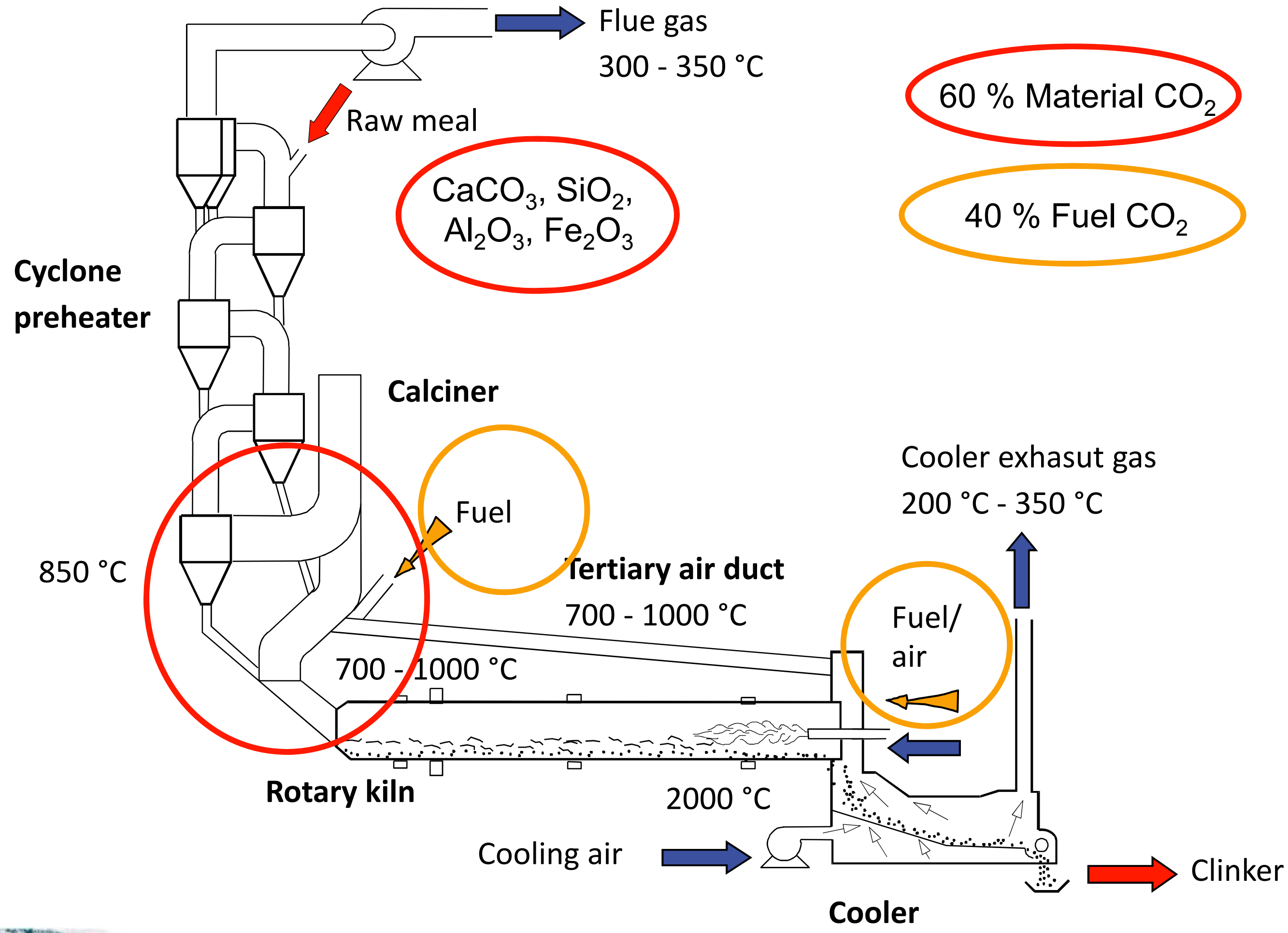
CO_2 emissions in the cement industry



Cement emissions represent 5% of total anthropogenic CO_2 emissions

Source: ECRA

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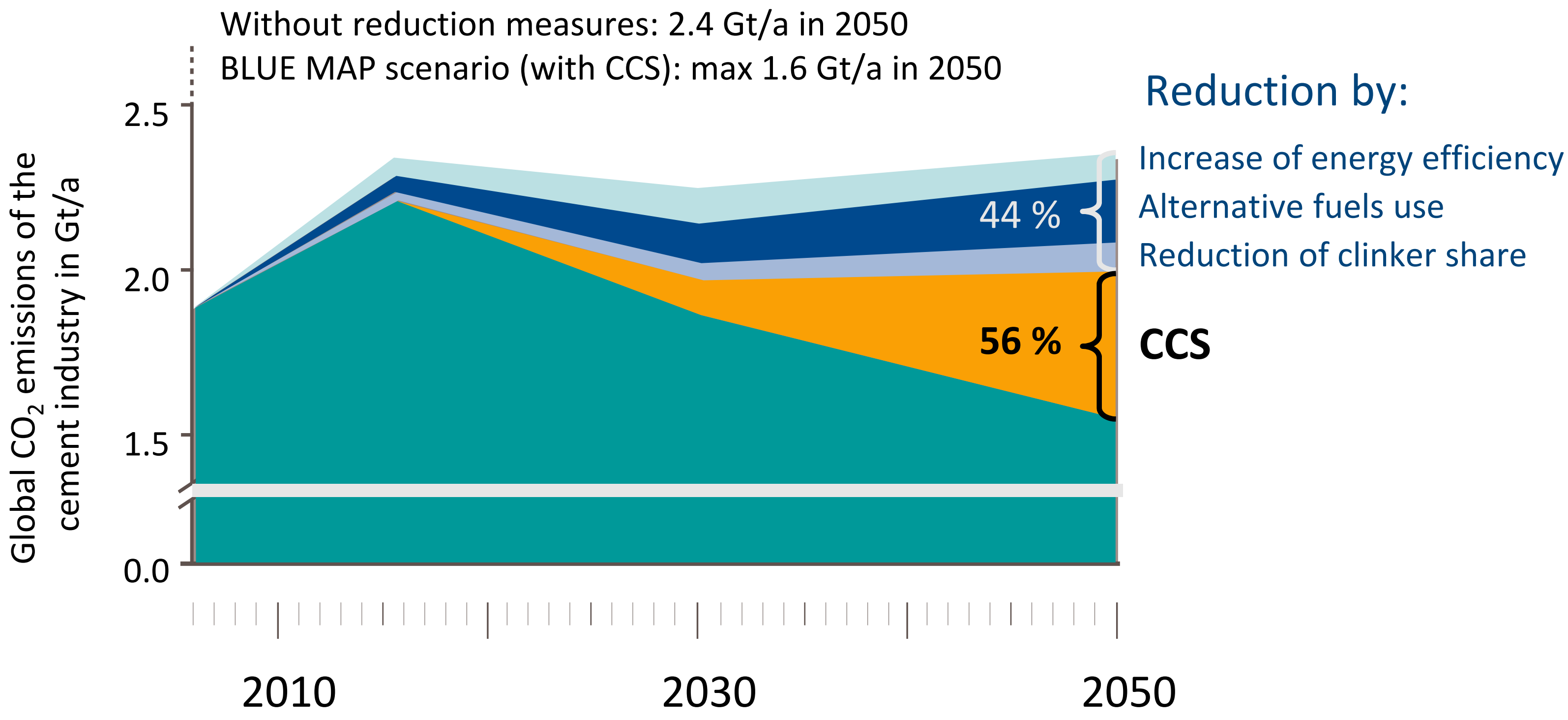
The need for CCS in Cement production



Source: IEA Cement Roadmap

- IEA target for 2050: 50 % of all cement plants in Europe, Northern America, Australia and East Asia apply CCS
- Cement plants typically have a long lifetime (30-50 years or more) and very few (if any) are likely to be built in Europe → Retrofit

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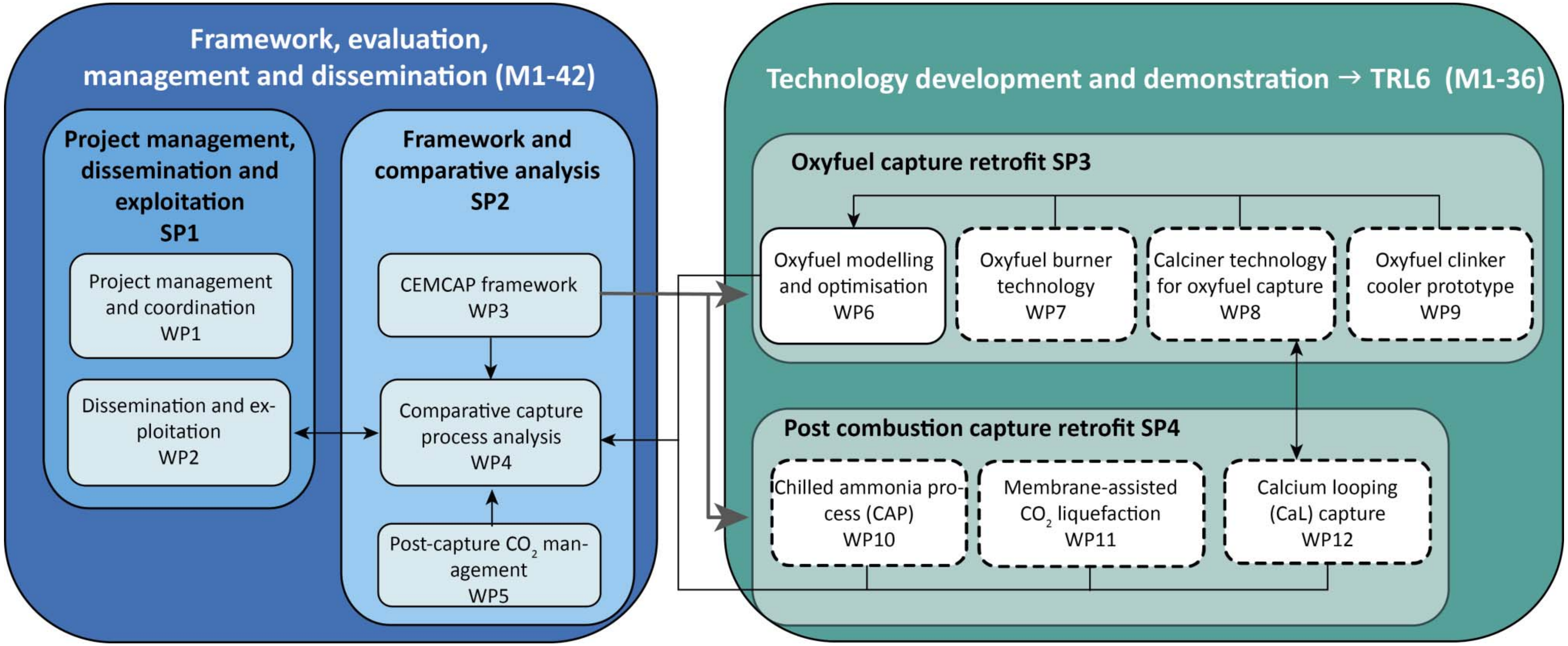
Project structure



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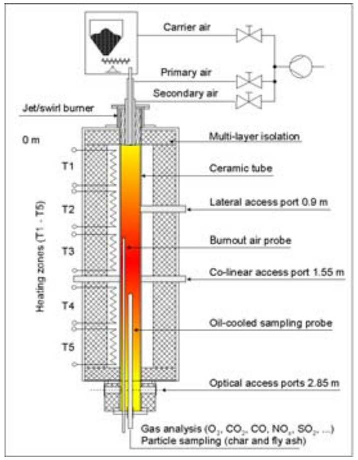
Technologies to be tested - oxyfuel

<u>Oxyfuel burner</u>
Existing 500 kWth oxyfuel burner at USTUTT to be modified for CEMCAP

Partners: USTUTT, TKIS, SINTEF-ER

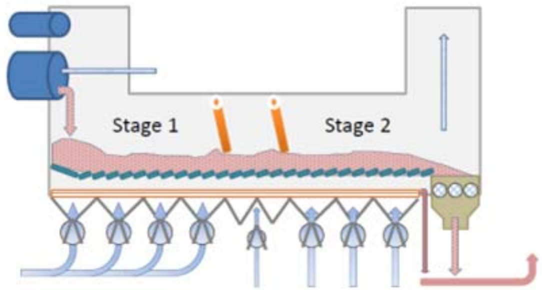
<u>Calciner test rig</u>

Existing <50 kWth entrained flow calciner (USTUTT) to be used for oxyfuel calcination tests



Partners: USTUTT, VDZ, IKN, CTG

<u>Clinker cooler</u> To be designed and built for on-site testing at HeidelbergCement in Hannover



Source: ECRA

Partners: IKN, HeidelC, VDZ

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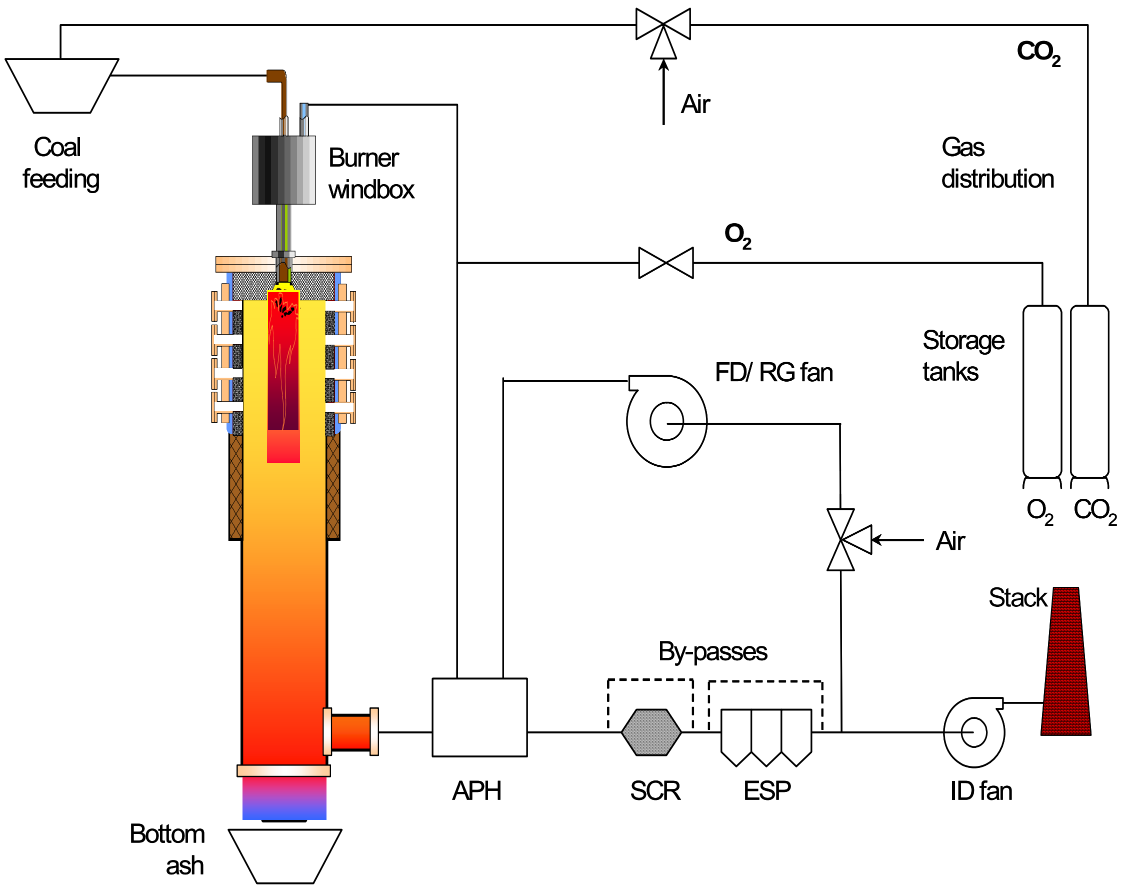
Outline

1. Validation of CFD models for oxy-fuel combustion.
2. Adaptation of test facility for cement kiln burner investigations.
3. Preliminary results of oxy-fuel investigations.

1. Validation of CFD models for oxy-fuel combustion.

➢ Simulation of USTUTT Combustion facility:



1. Validation of CFD models for oxy-fuel combustion.

- Simulation of oxy-fuel test at USTUTT Combustion facility with IFK burner:

Test case	O_2 in oxidizer [vol-% wet]	Stoichiometric ratio	O_2 in stack [vol-% dry]	Fuel input [kW]
Air	21	1,15	2,8	305
OF29	29,5	1,15	4,5	305

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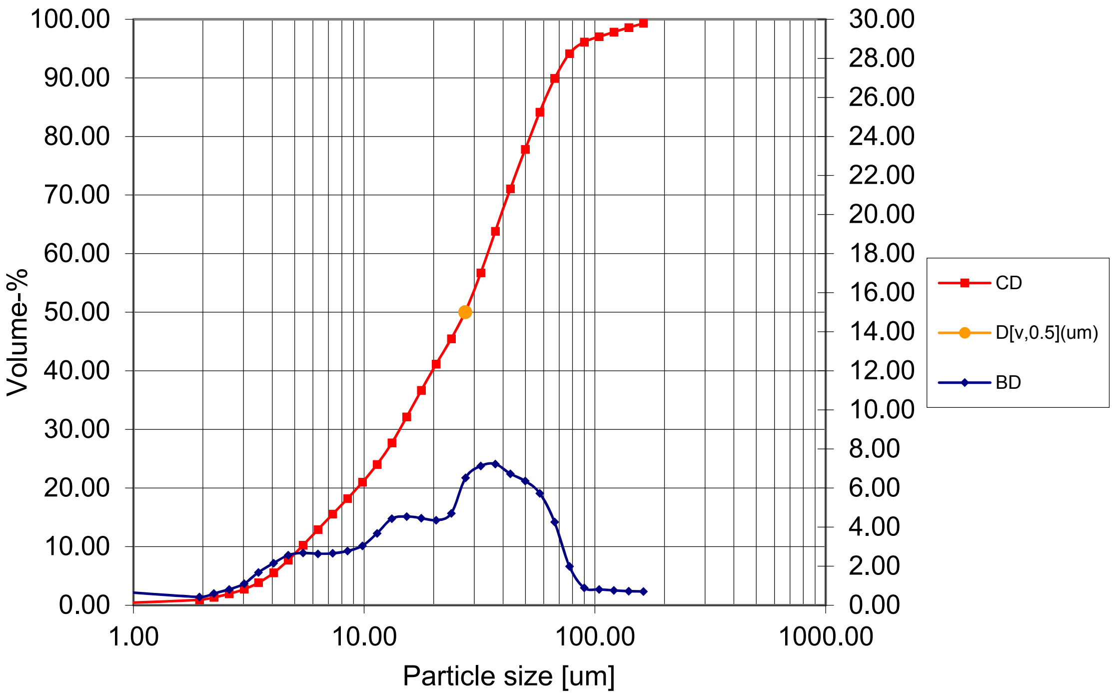
1. Validation of CFD models for oxy-fuel combustion.

- South African coal:

	Water [%]	Ash [%]	Volatiles [%]	Cfix [%]	C [%]	Htot [%]	H [%]	N [%]	S [%]	O [%]
an	1,65	14,36	27,22	56,77	67,83	4,77	4,59	1,77	0,44	9,35
raw	8,94	13,30	25,20	52,56	62,80	5,25	4,25	1,64	0,41	8,66
wf	-	14,61	27,67	57,72	68,97	4,67	4,67	1,80	0,45	9,51



	$H_{o,v}$ [J/g]	$H_{u,p}$ [J/g]
an	27.383	26.355
raw	25.444	24.316
wf	27.942	26.943
waf	32.721	31.551
Ho,v = HHV and Hu,p = LHV		

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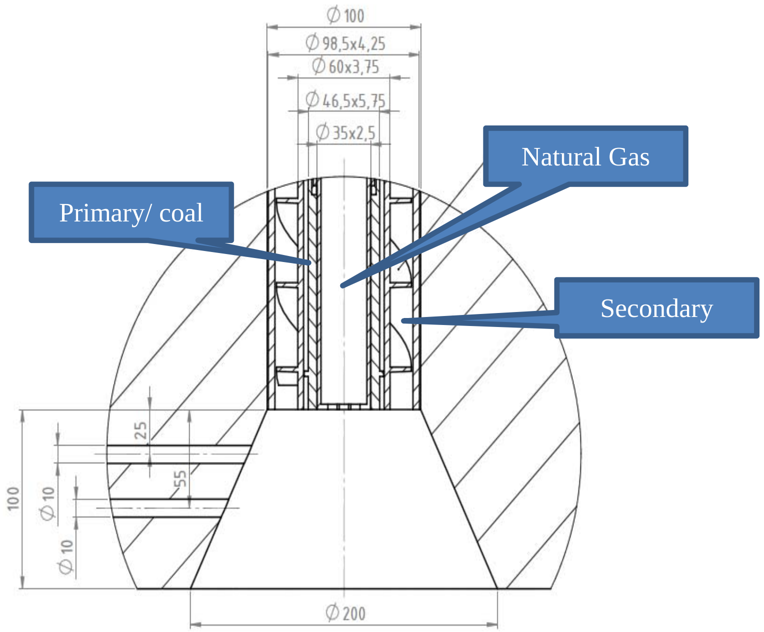
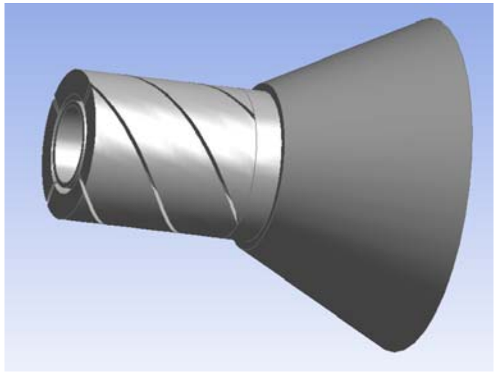
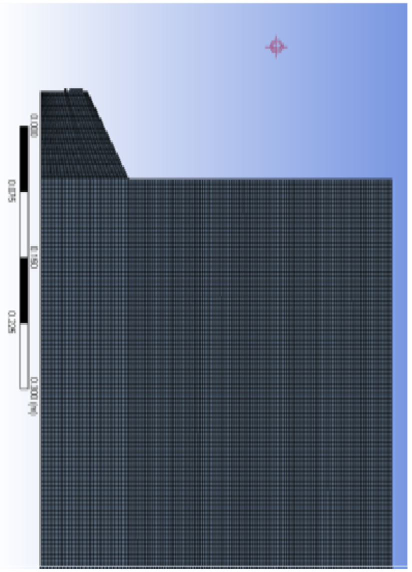
1. Validation of CFD models for oxy-fuel combustion.





CFD input

	Ansys Fluent models
Code	Fluent 17.0 2D-Axisymmetric swirl
Mesh, number of cells	113757 (structured mesh)
Turbulence	k-epsilon, realizable, standard wall functions k-omega SST
Chemistry	Species transport, Finite rate/Eddy Dissipation, 2-step reaction
Radiation	P1 with particle-radiation interaction
Furnace wall temperature	Profile calculated from IFK experiments. Implemented by an UDF
Inlets	Velocity inlet (constant velocity)
Outlet	Pressure outlet



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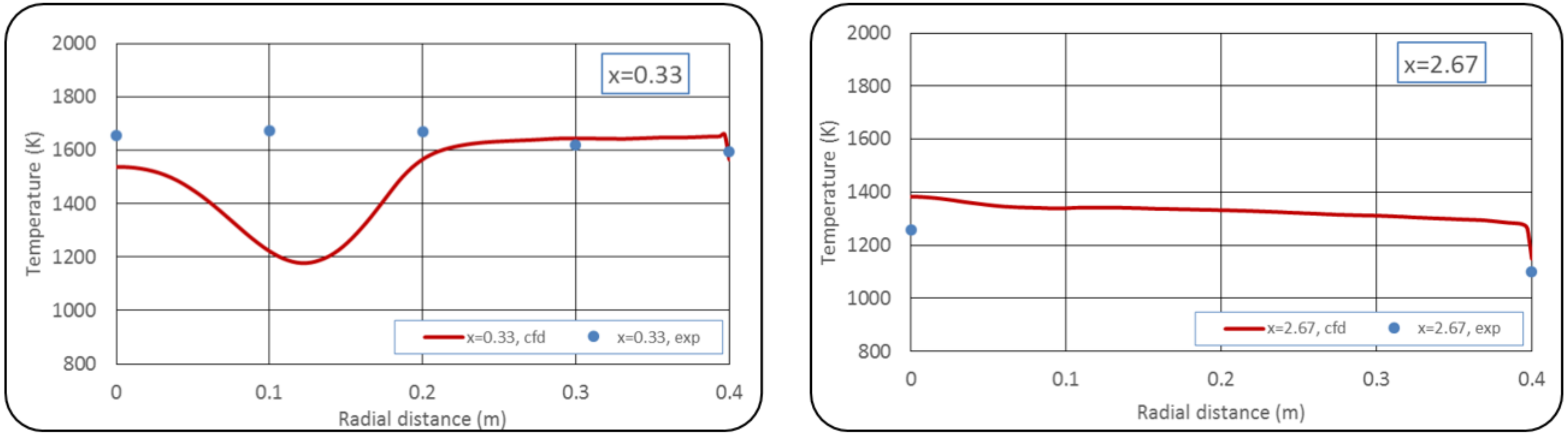
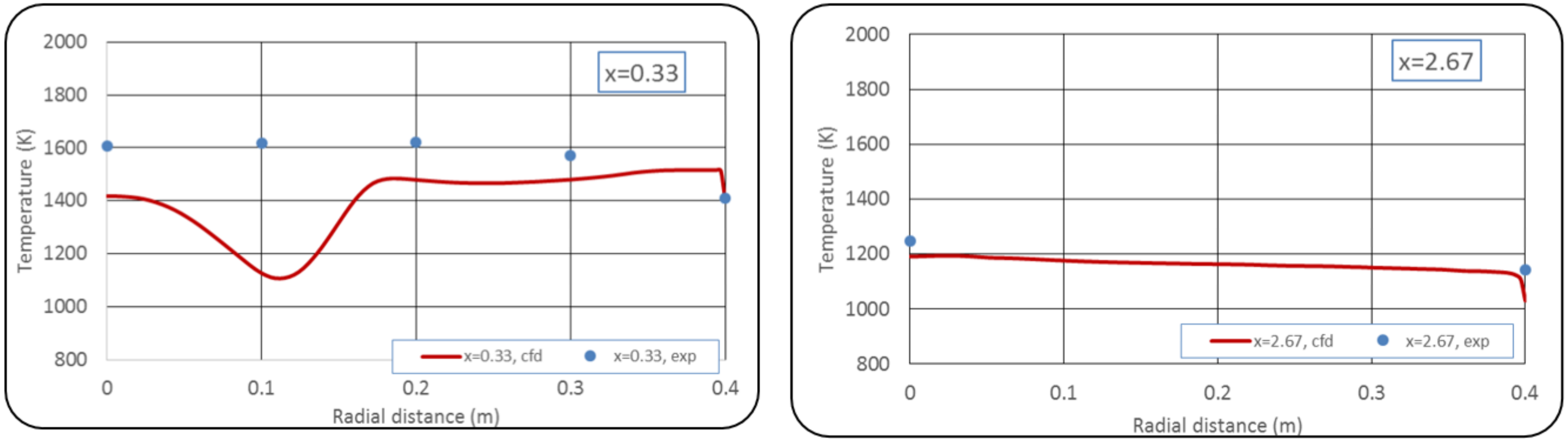
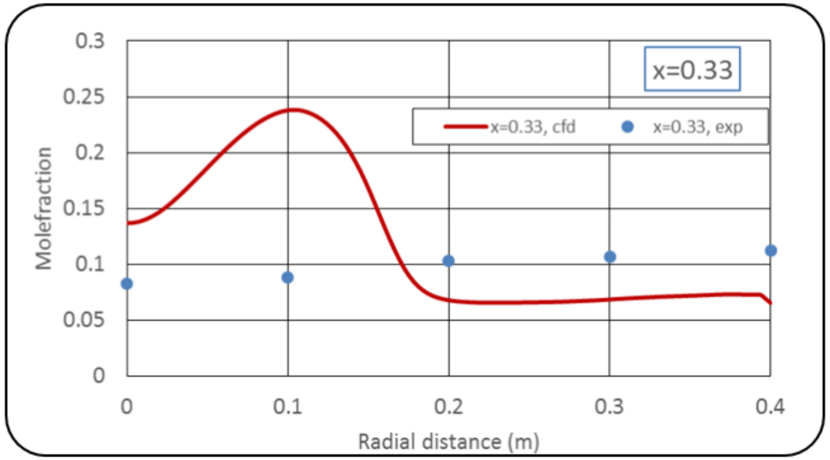
Temperature profile – Air Case

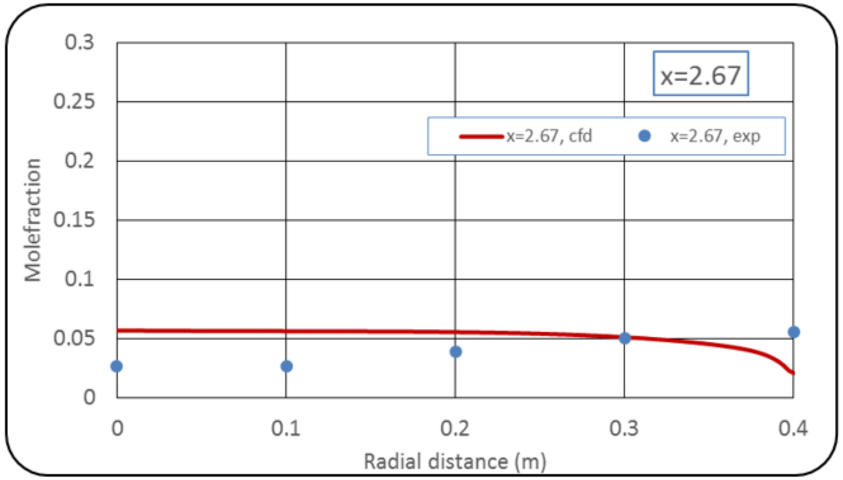


Temperature profile – Oxy-fuel Case

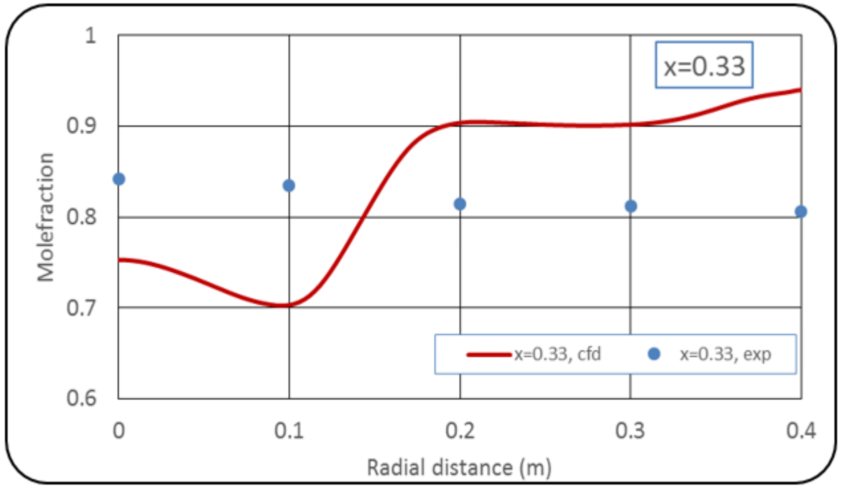


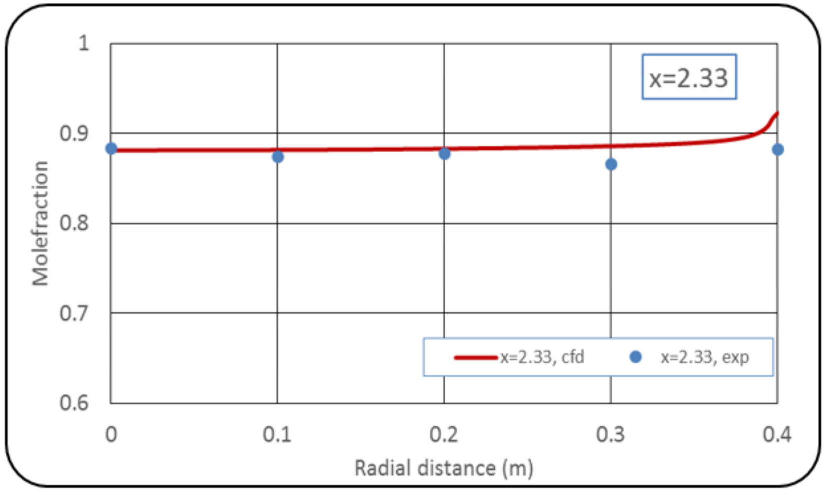
Oxygen profile – Oxy-fuel Case





Carbon dioxide– Oxy-fuel Case





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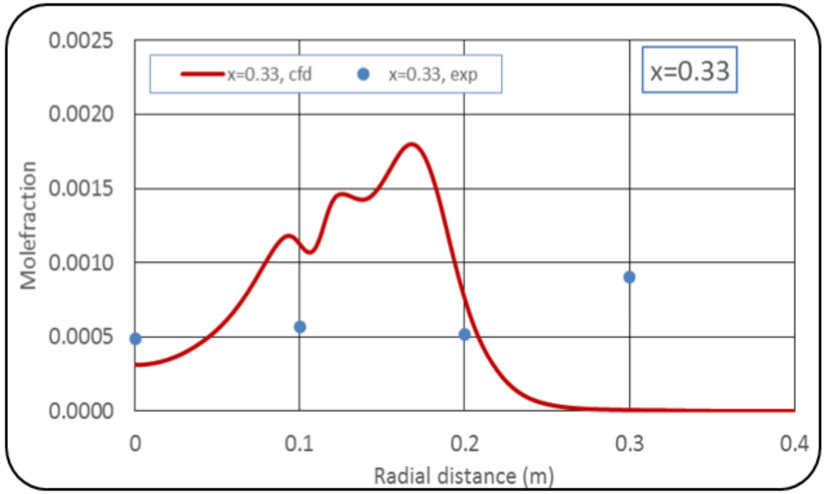
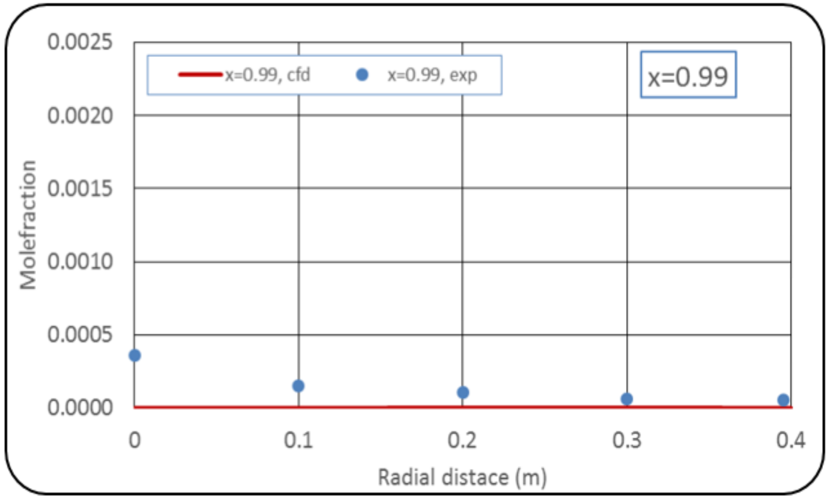
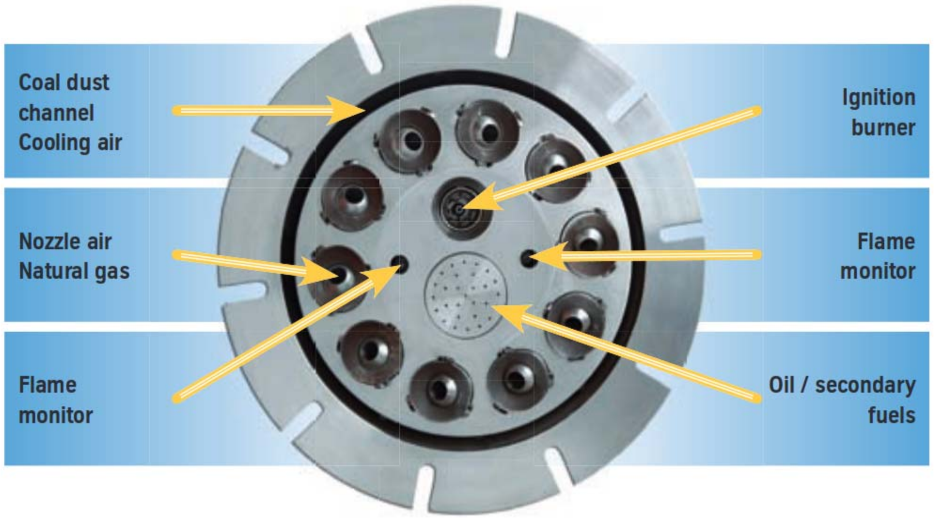
Carbon Monoxide profile – Oxy-fuel Case





2. Adaptation of test facility for cement kiln burner investigations.

a) Design of a prototype oxy-fuel burner for cement kilns.



Source: ThyssenKrupp- POLFLAME

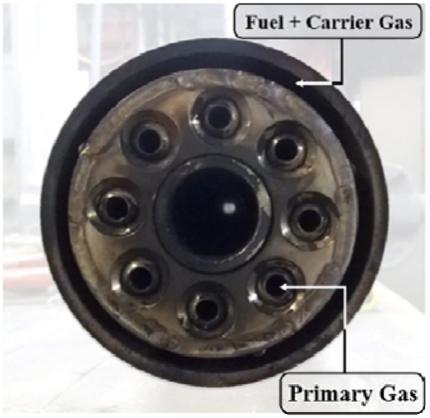
Source: ThyssenKrupp

- Scaling factor of 100 between industrial and pilot burner.

2. Adaptation of test facility for cement kiln burner investigations.

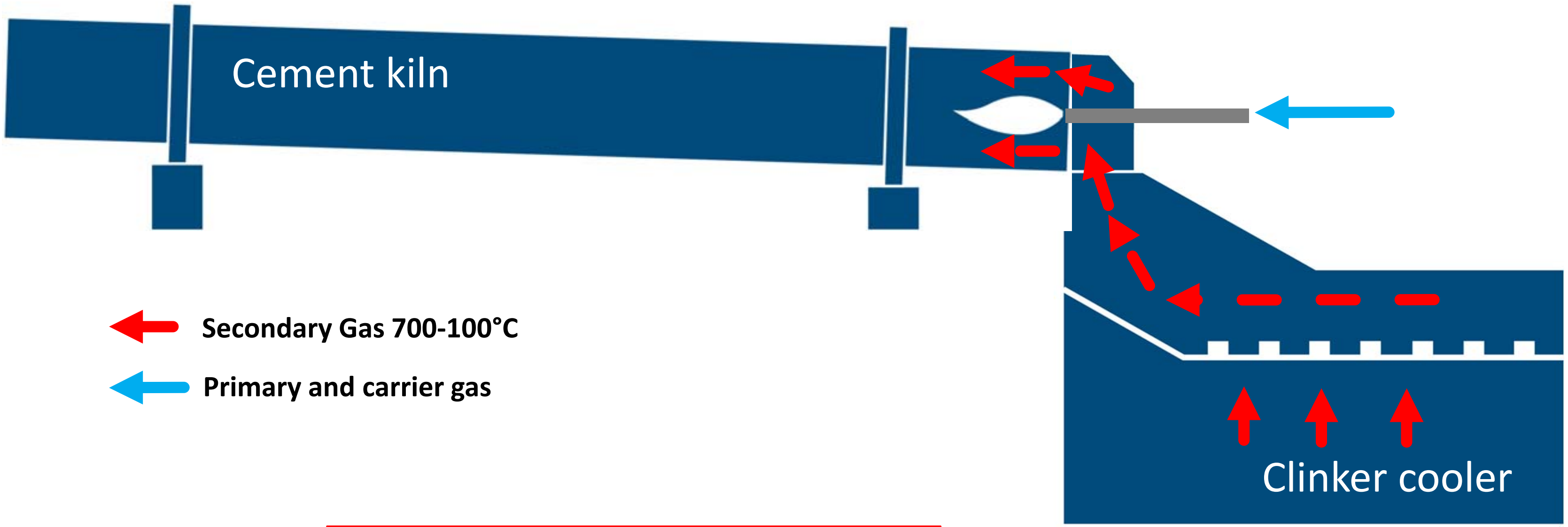
- Primary Gas (nozzles)
  - Velocity ca. 250 m/s
  - 8 nozzles
  - Angle: 0-40°

- Carrier gas (outer coal channel)
  - Transport air velocity ca. 15 m/s



2. Adaptation of test facility for cement kiln burner investigations.

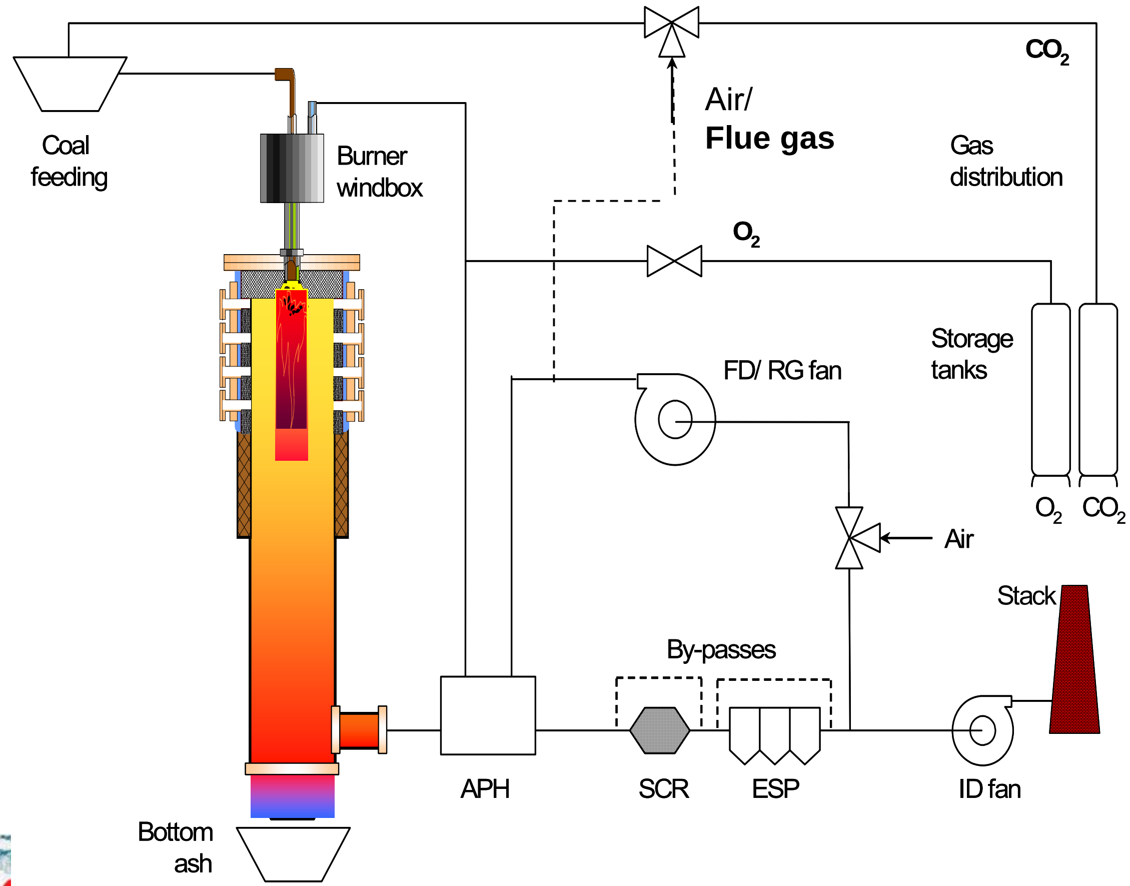
b) Adapt test facility for oxy-cement processing

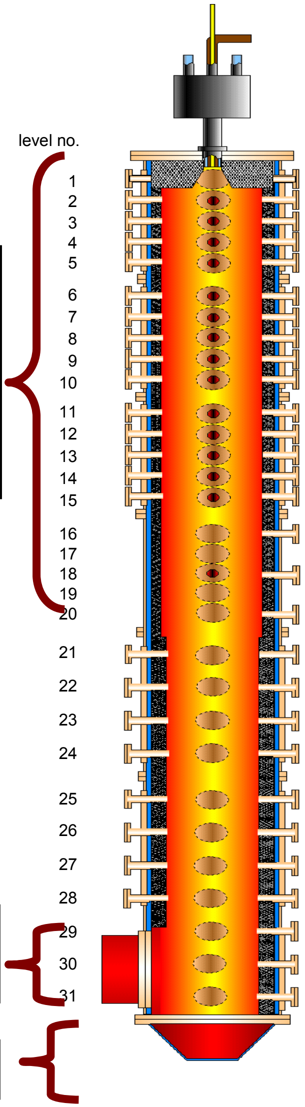


- Preheating of secondary gas
- Dry secondary gas

2. Adaptation of test facility for cement kiln burner investigations.

Test facility: 500 kW_{th} KSVA (Pulverized Coal Combustion Plant)





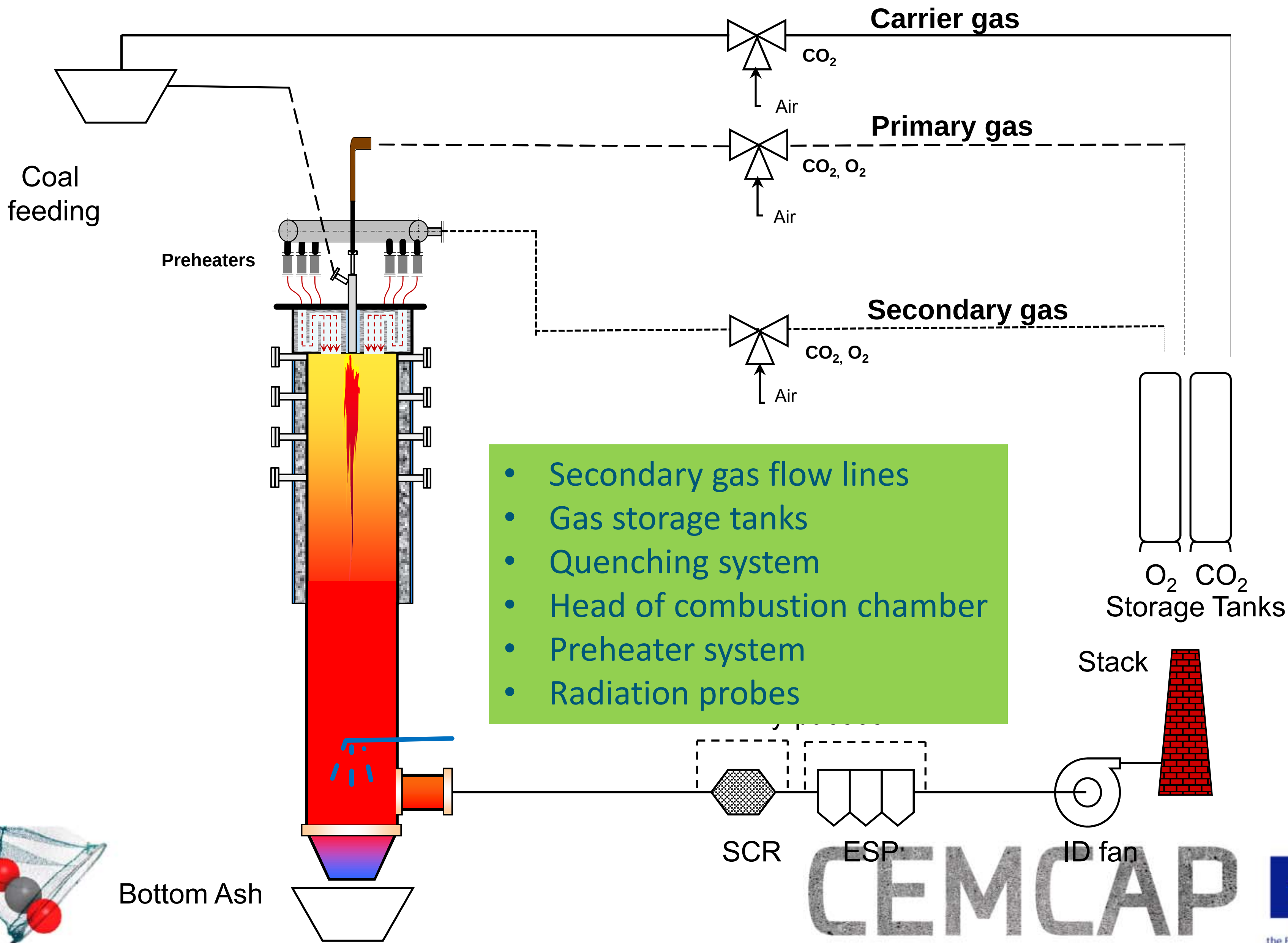
In-flame Measurements:

- Gas emissions
- Gas temperature
- Heat flux
- Radiation, etc.

Continue gas measurements

Burn out

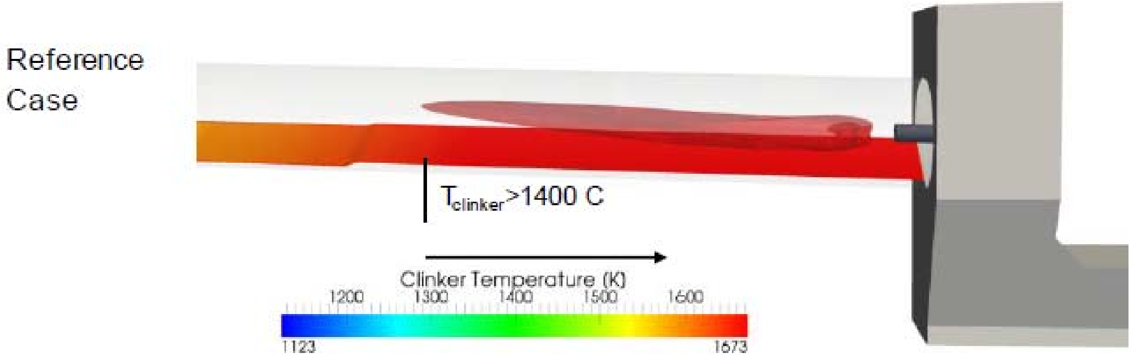
2. Adaptation of test facility for cement kiln burner investigations.

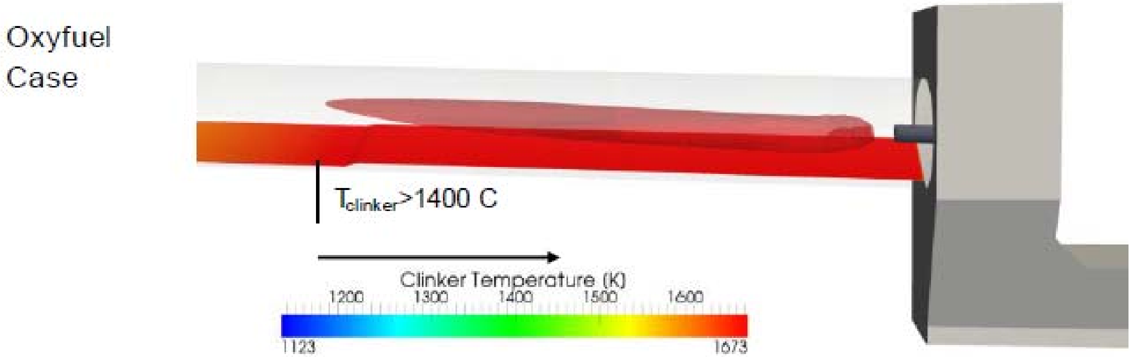


- Secondary gas flow lines
- Gas storage tanks
- Quenching system
- Head of combustion chamber
- Preheater system
- Radiation probes

3. Preliminary results of oxy-fuel investigations.

Previous results published by ECRA:

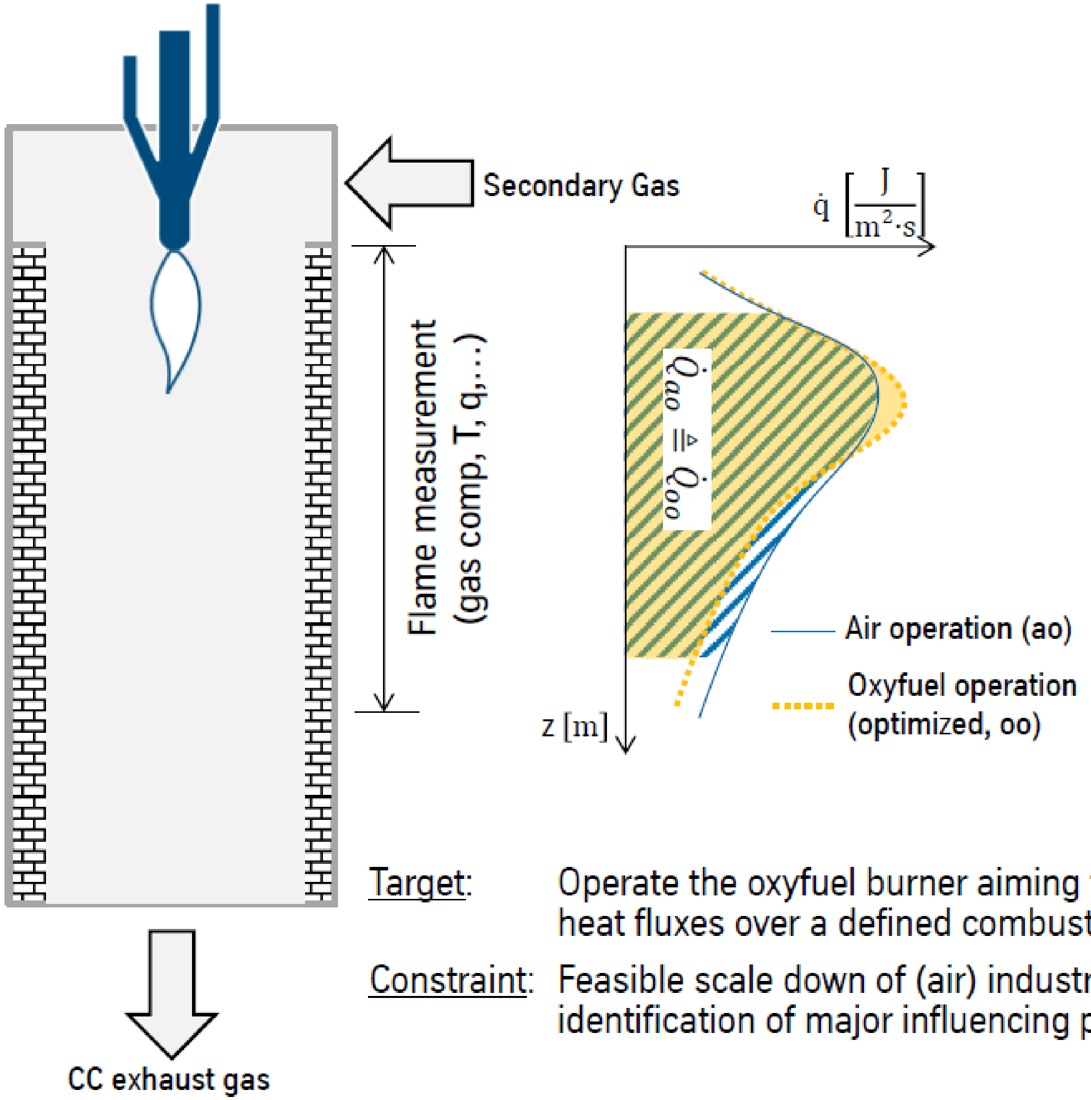




- Longer flame.
- Altered temperature profile.
- Altered heat flux profile to material bed.

Source: ECRA CCS Project

Proposed validation oxyfuel vs. air operation



<u>Target</u>: Operate the oxyfuel burner aiming to achieve equal heat fluxes over a defined combustion chamber length

<u>Constraint</u>: Feasible scale down of (air) industrial burner, identification of major influencing parameters

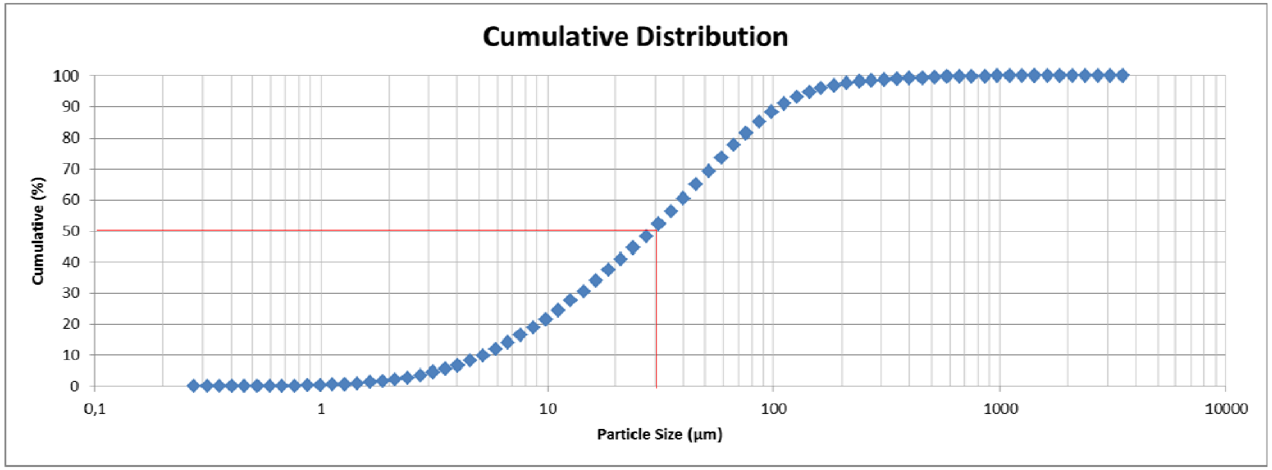
Source: ThyssenKrupp

3. Preliminary results of oxy-fuel investigations.

Fuel characterization: **Petcoke**

	Water [%]	Ash [%]	Volatiles [%]	Cfix [%]	C [%]	Htot [%]	H [%]	N [%]	S [%]	Cl [%]
an	4,56	2,12	11,3	82,0	77,0	3,91	3,40	1,47	3,03	0,074
wf	-	2,22	11,9	85,9	80,7	3,56	3,56	1,57	3,17	0,078

	$H_{o,v}$ [J/g]	$H_{u,p}$ [J/g]
an	33.077	32.237
wf	34.657	33.894
Ho,v = HHV and Hu,p = LHV		



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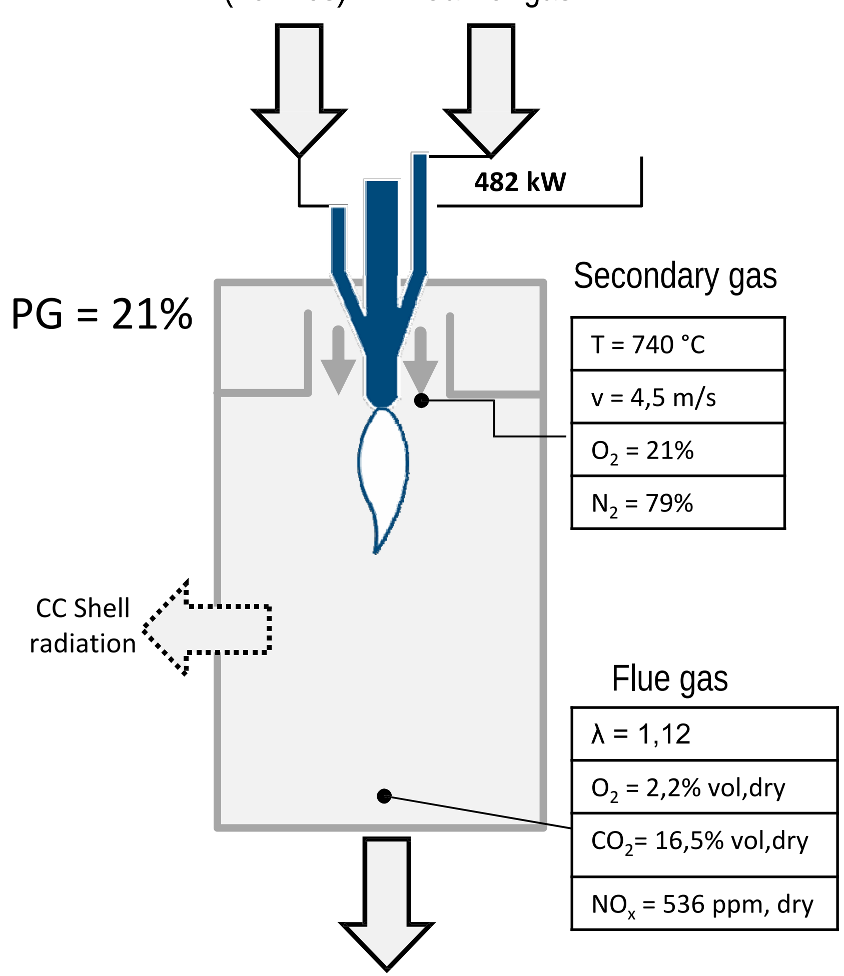
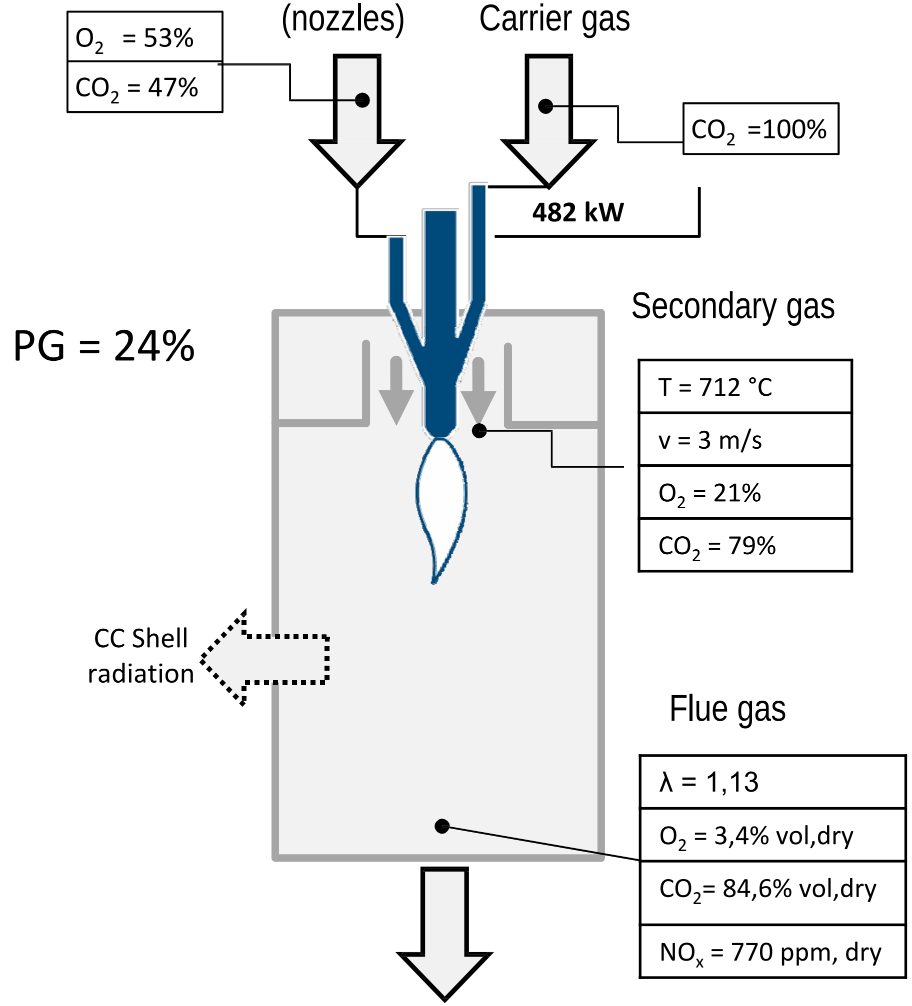
AIR CASE

OXY-27

Swirling 40°





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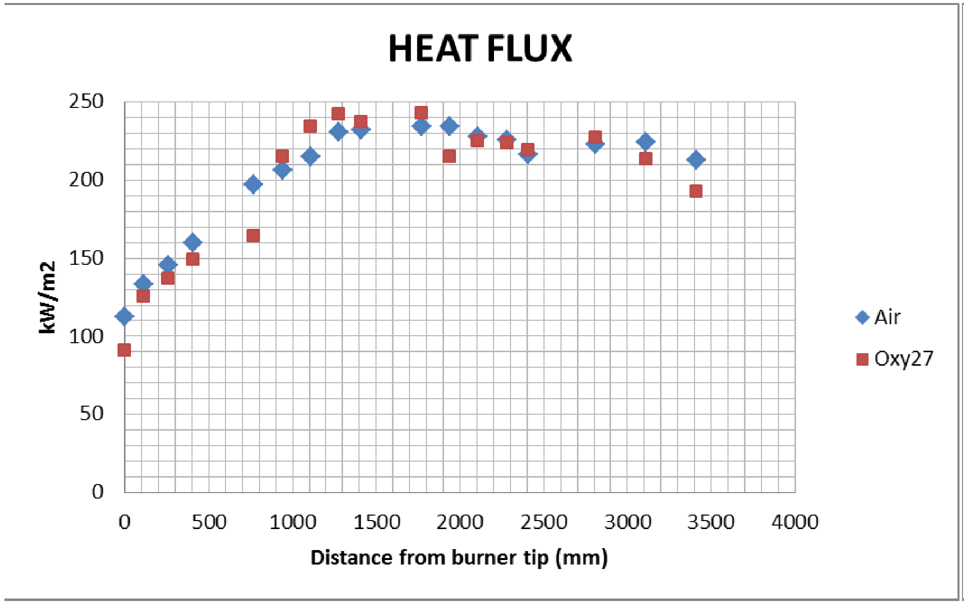
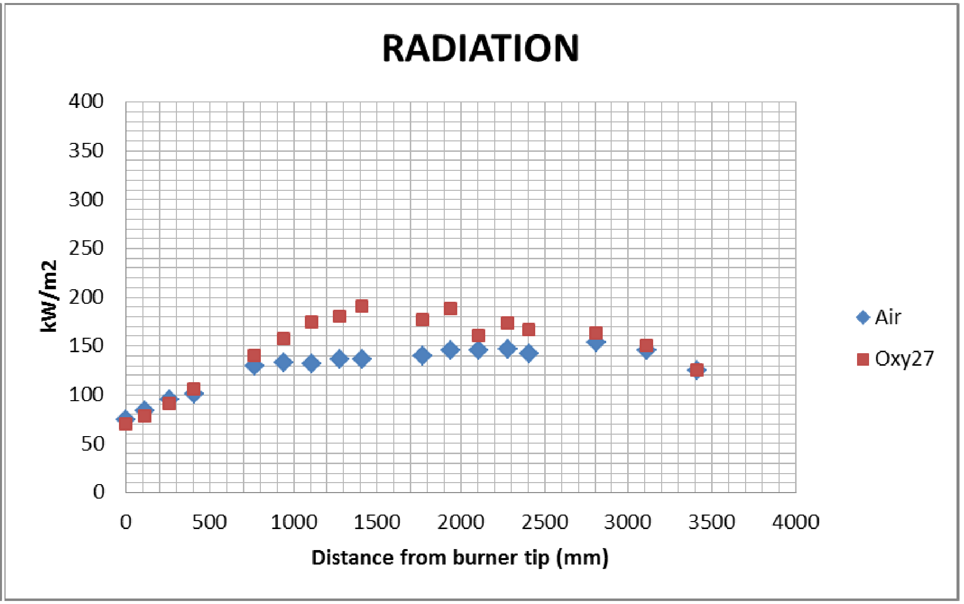
3. Preliminary results of oxy-fuel investigations.





	Air Case	Oxy-fuel
Fuel burnout	98,0	98,3

Summary

- First simulation of test rig. Validation vs Experimental data was successful.
- Two turbulence models were tested, K-Omega produced better results.
- Test facility was adapted for relevant oxy-cement tests.
- Burner prototype was designed and tested.
- Demonstration tests evinced suitability to obtain similar radiation profiles under oxy-fuel conditions.

Further Steps

- Additional testing with a higher volatile fuel.
- Simulation of additional oxy-fuel cases not investigated in facility.

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