Overview of Burner tests in Vattenfall's Oxyfuel Pilot Plant

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Base data and Technology partners

Thermal capacity:	30 MW_{th}
Coal demand:	5.2 t/h
Investment	80 Mio. €
Total costs	150 Mio. €

- **Start up test operation Sept. 2008**
- **Until 17.000 operating hours in total, from it 13.200 in Oxyfuel mode, captured CO_2 approx. 10.660 t**
- **CO_2 removal rate > 90 %**
- **High plant availability**
- **Good CO_2 quality for transport, storage and CCU**

Technology partner :

ALSTOM

Linde

HITACHI Inspire the Next

BABCOCK NOELL

DOOSAN

Babcock Borsig Steinmüller

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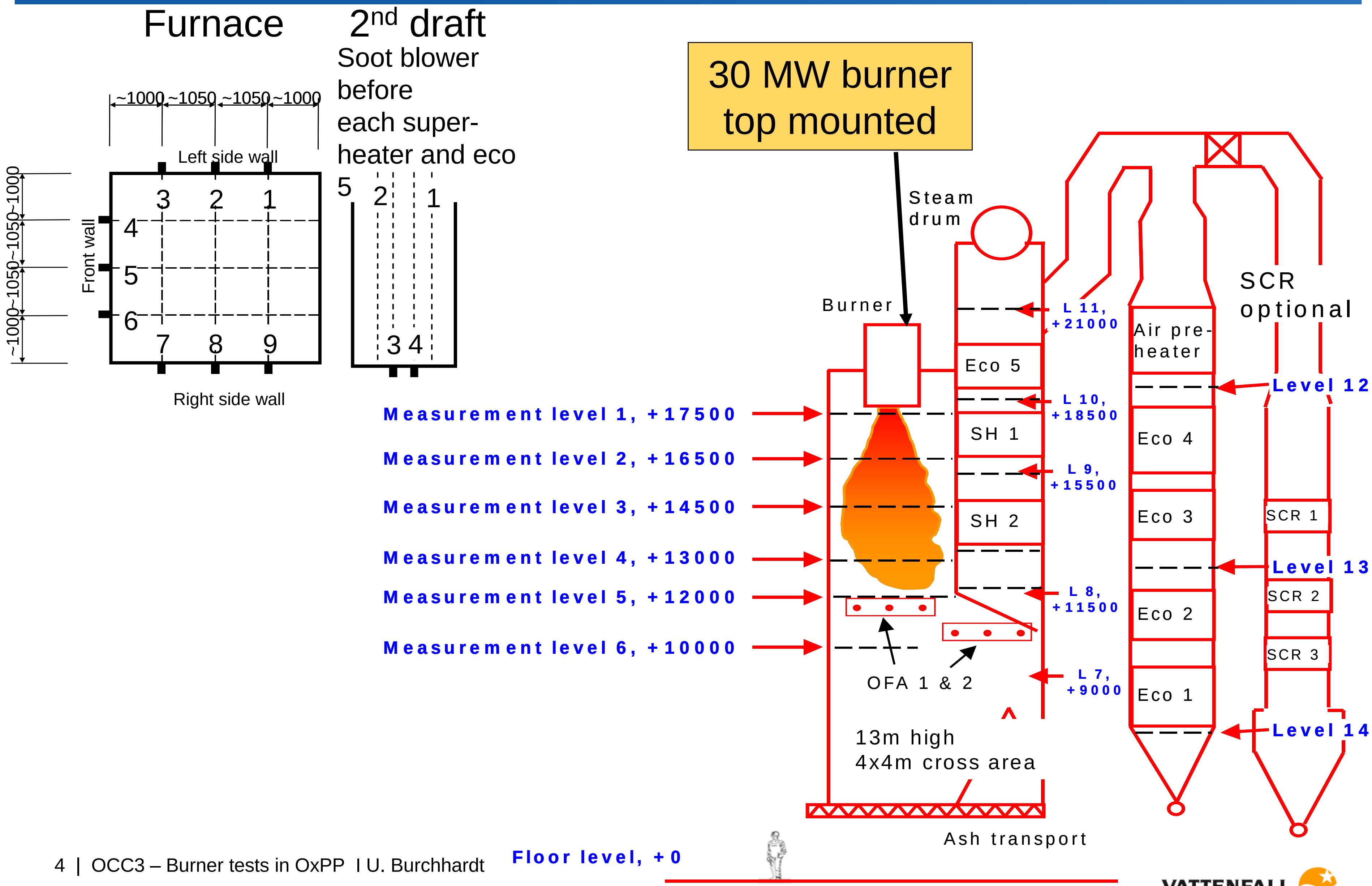
Boiler and Measurement points



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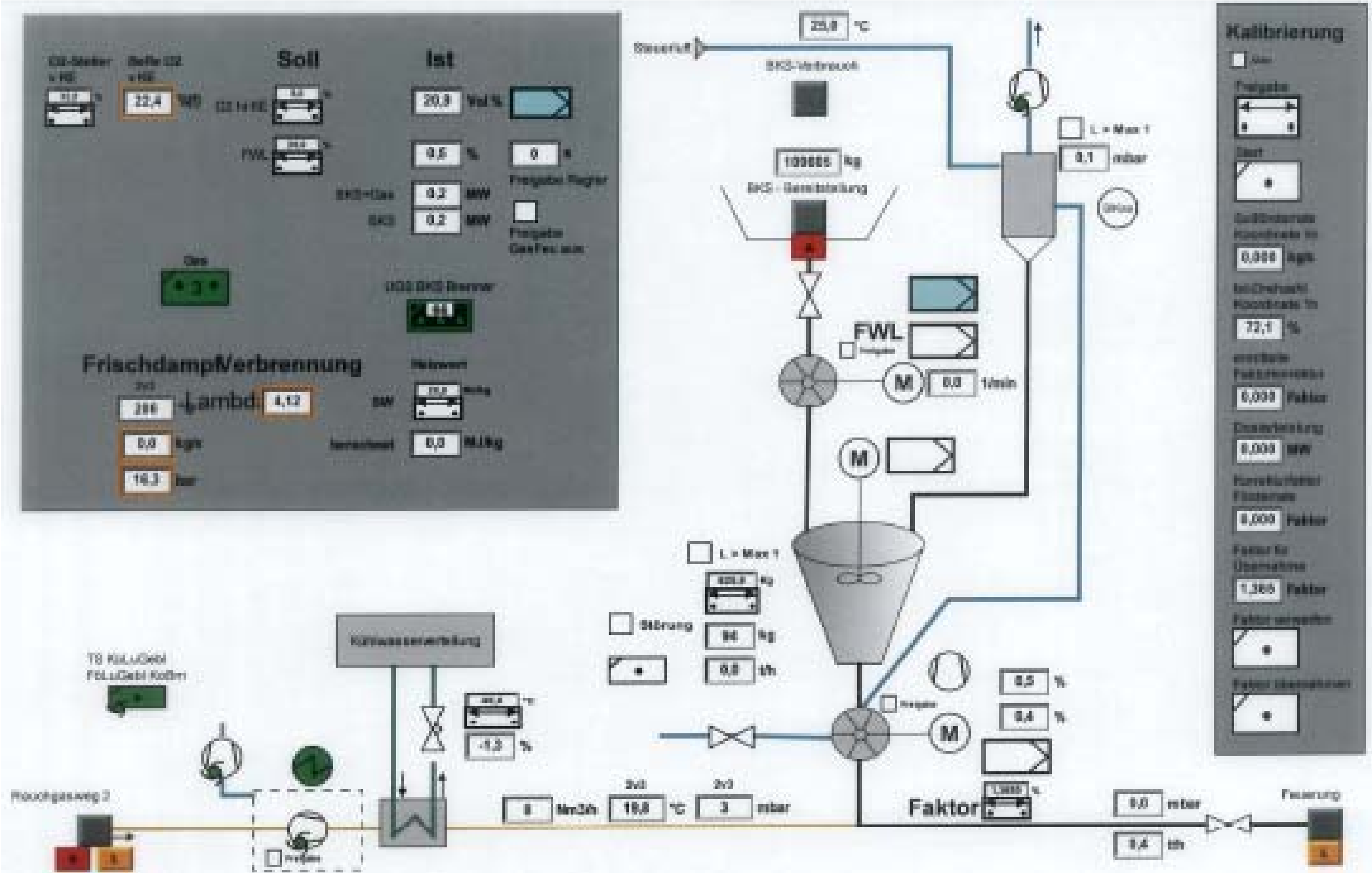
Direct coal dosage to burner



➔ Combustion behaviour can only be judged in connection with coal dosage

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Requirements on burners

Burner characteristic	Requirements
Fast start ability, stable ignition, stable flame	- Ignition within 5 seconds - Hot-, warm- and cold start ability
High combustion quality: - low excess O_2 - emissions - unburned	 - O_2 excess in flue gas (downstream boiler) < 4% - compliance emission limits (CO, NOx, dust) - unburned in ash < 2%
Flexibility for fuel quality	- high range of particle size distribution - Variation to LHV
Transport and combustion gas	- Combustion gas: air or O_2-mixed flue gas (21%-39%) - Fuel transport gas: air or CO_2-rich flue gas - Fuel loading up to 5 kg / kg transport gas
Possibility to swirl of secondary airs	- Optimal intermixing of coal stream by swirl of secondary airs - Influence on flame characteristics regarding heat transfer behaviour

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Overview of tested burner

Burner 1: comb. Jet-/swirl burner

Burner 3: pure swirl burner

Burner 5: swirl burner with pre-mix possibility

2008

2009

2010

2011

2012

Burner 2: pure swirl burner

Burner 4: swirl burner as pre-mixed burner

Overview of constructions

Burner type	Characteristics
Combined Jet-/swirl burner	- concentric formation of one core pipe for oxidant supply, one fuel/transport gas and **three** secondary oxidant cross-sections - length of flame nearly up to exit of firth path of the boiler
Pure swirl burner	- concentric formation of one core pipe for oxidant supply, one fuel/transport gas and **two** oxidant cross-sections - Conduct of flame with a high swirl rate - Flame is short and shows characteristic bell shape
Pre-mixed swirl burner	- concentric formation of one core pipe for oxidant supply, one fuel/transport gas and **three** secondary oxidant cross-sections - swirl generator located in secondary and tertiary oxidant supply. Option to modify the angle of swirl generator - Injection of fuel directly into third oxidant supply cross section

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2	Requirements on burners for Air and Oxyfuel
3	**Tests and results of different burner types**
4	Outlook : The electrical ignition burner
5	Summary

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Overview of burner tests

- Flame characteristics and heat transfer
- Switch from Air to Oxyfuel operation and back
- O_2 concentration in combustion air (burner lambda, boiler lambda)
- Reduction O_2 excess at compliance emission values
- Swirl variation
- In-flame measurements
- Optimization firing behaviour with variation OFA
- part load behaviour
- different lignite qualities (sulfur, particle size distribution)

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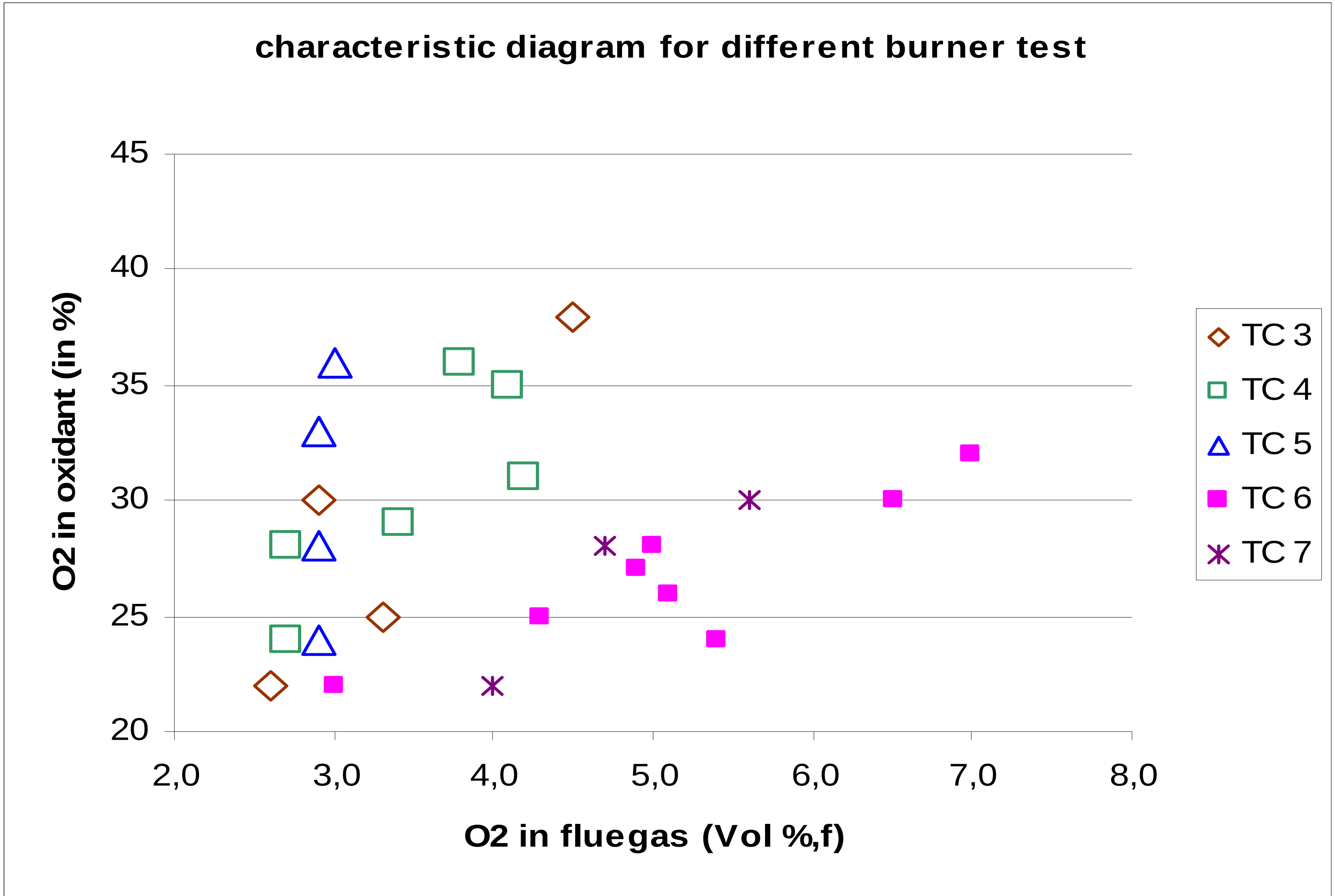
Comparison of operational points in Oxyfuel



TC = Test Campagne of burners

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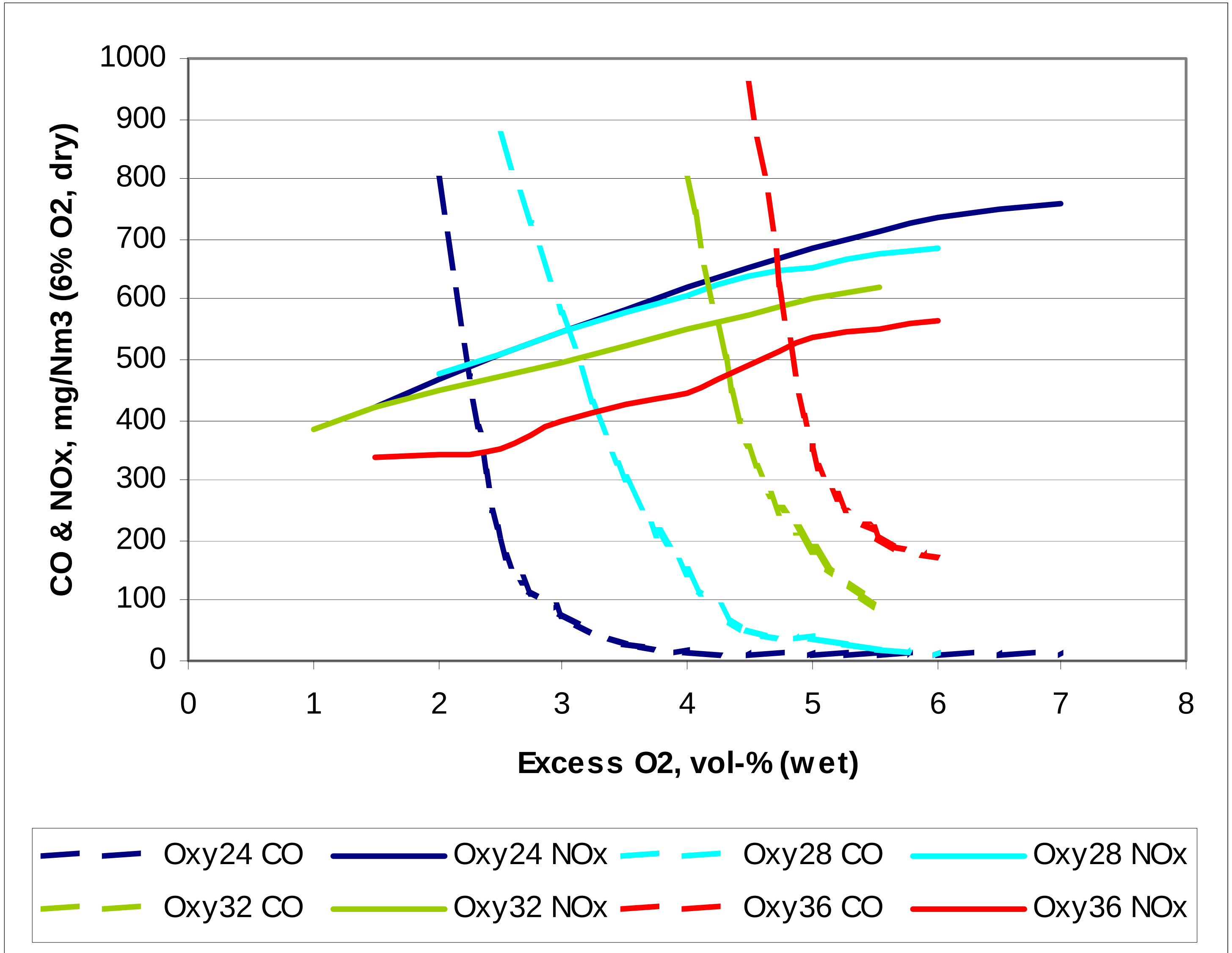
Emissions in Oxyfuel: NOx, CO vs. excess O_2 (TC 5)



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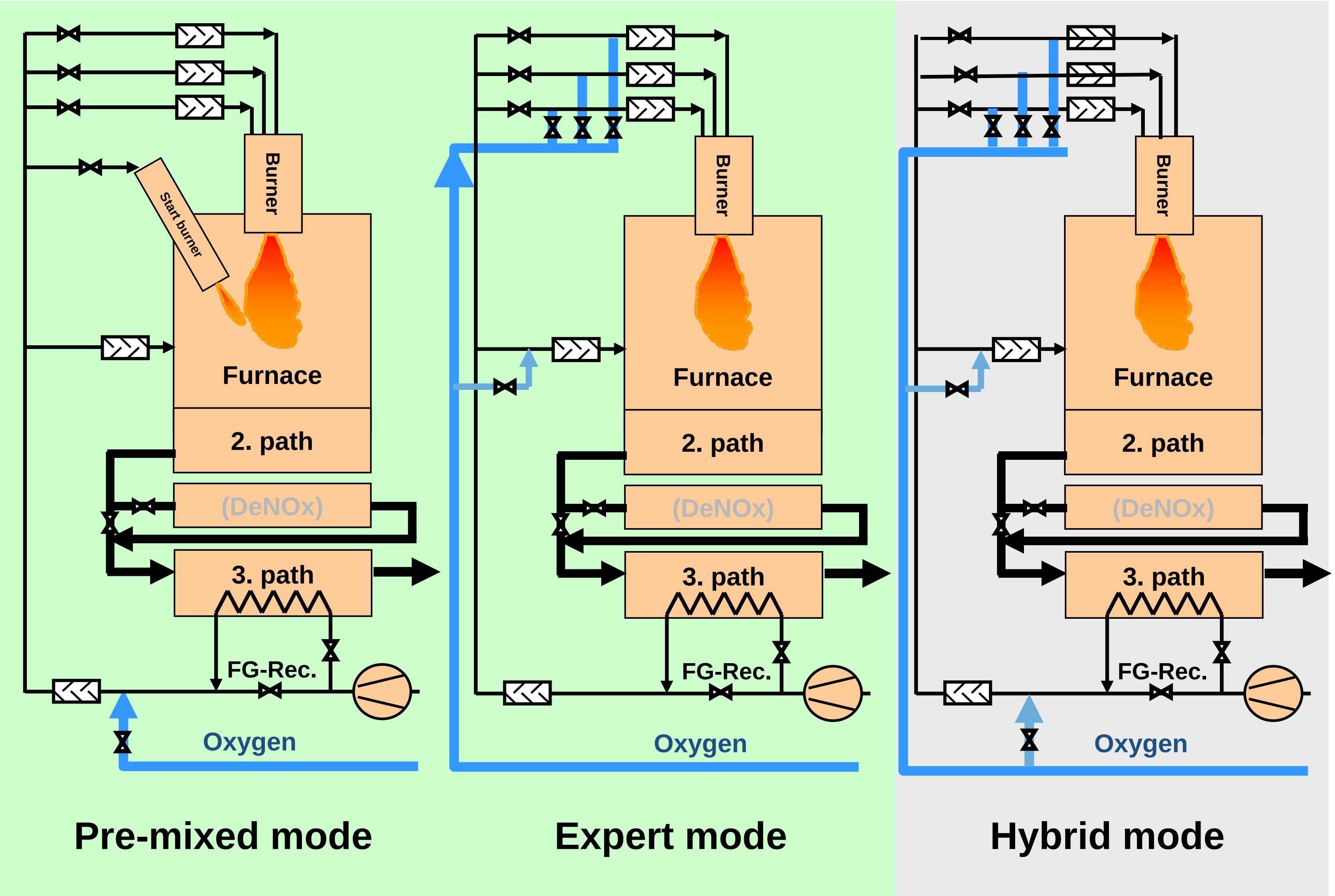
O_2-Mix: Pre-mixed mode, Expert mode und Hybrid mode



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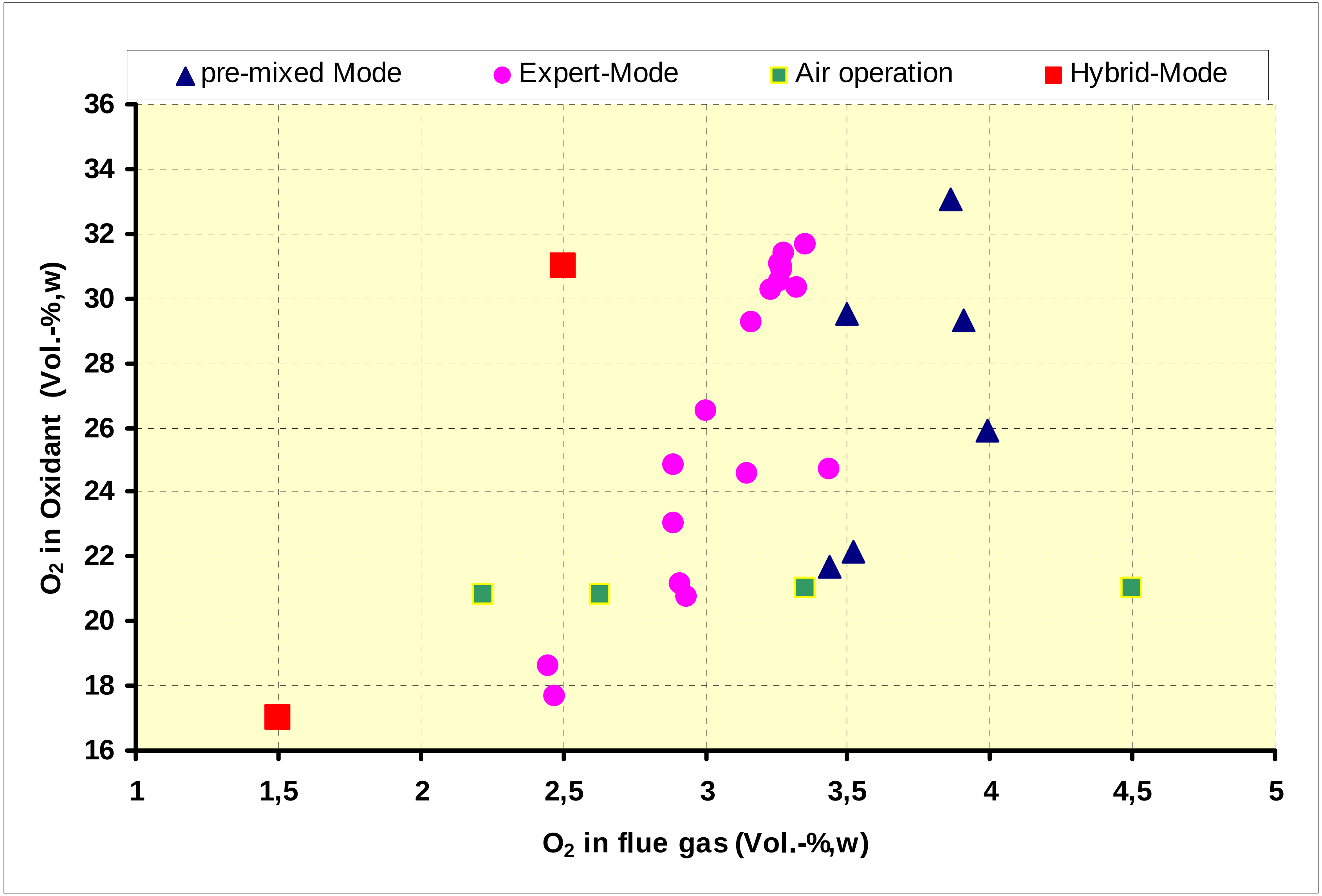
Comparison of burner operational area on varied operation mode and in respect to emission limits



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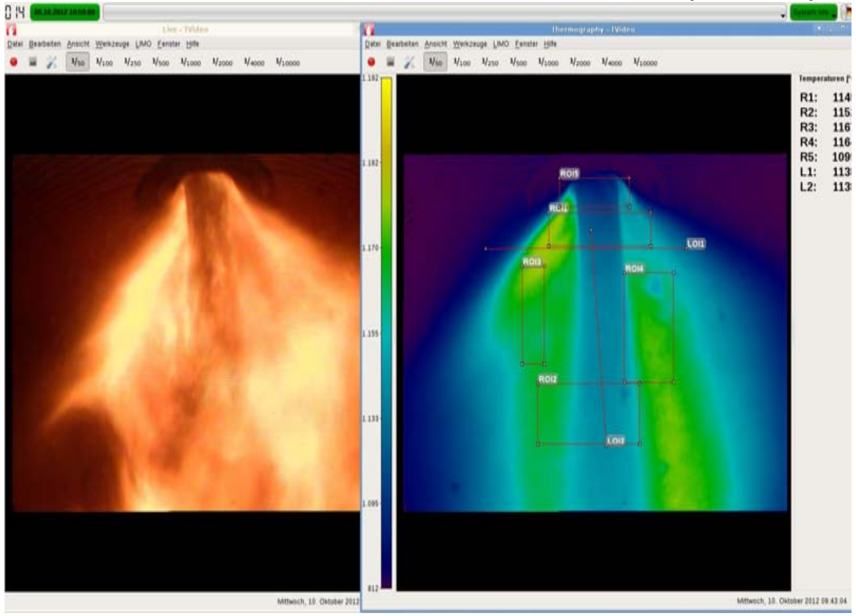
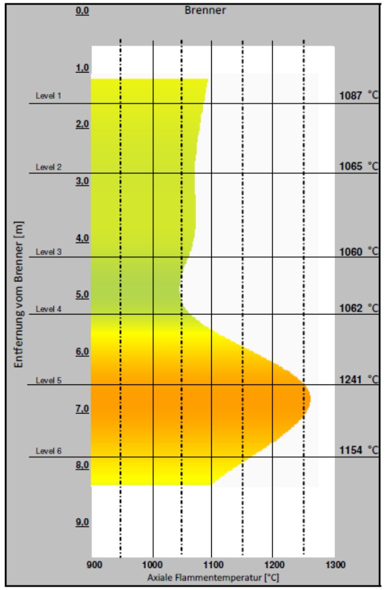
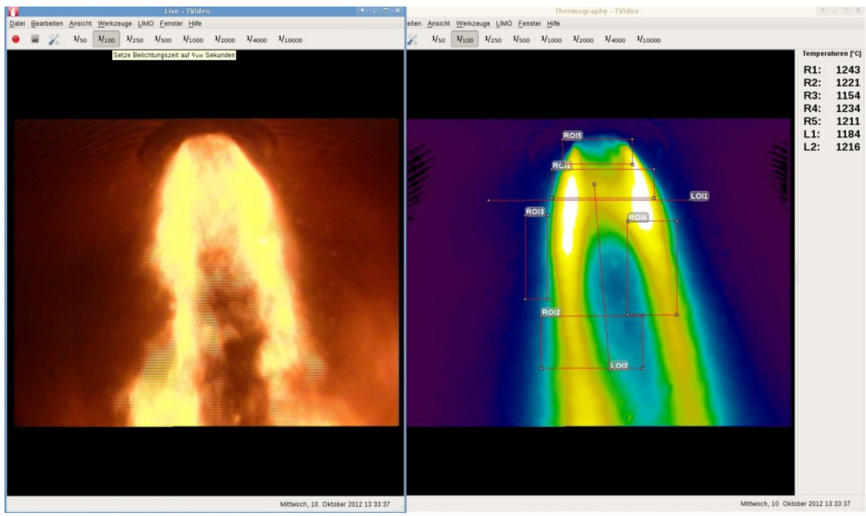
Influence of swirl change on flame shape and temperature

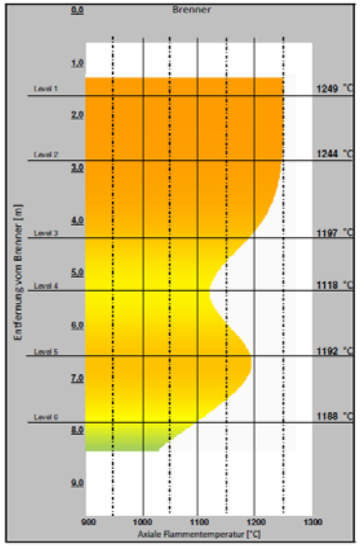
Furnace camera | Thermovisions camera (DURAG) | CombTec-Measurement





Before adjustment swirl SA1/SA2





After adjustment swirl SA1/SA2

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Overview of burner tests

Burner tests	Results
Flame characteristics and heat transfer	Stable flame without pulsation, - Flame shape (volume and length)
Switch from air to Oxyfuel operation and back	In general in 20 minutes realized
O_2 concentration in combustion air (burner lambda, boiler lambda) Reduction O_2 excess at compliance emission values	Variation O_2 content 21% to 39% in different burner register Stable operation < 3% O_2 excess possible
Swirl variation	Swirl of secondary air flows necessary
In-flame measurements	Validation for CFD burner model possible
Combustion behaviour with variation OFA (staged combustion)	Optimisation OFA has influence of combustion behaviour (reduce NOx/CO)

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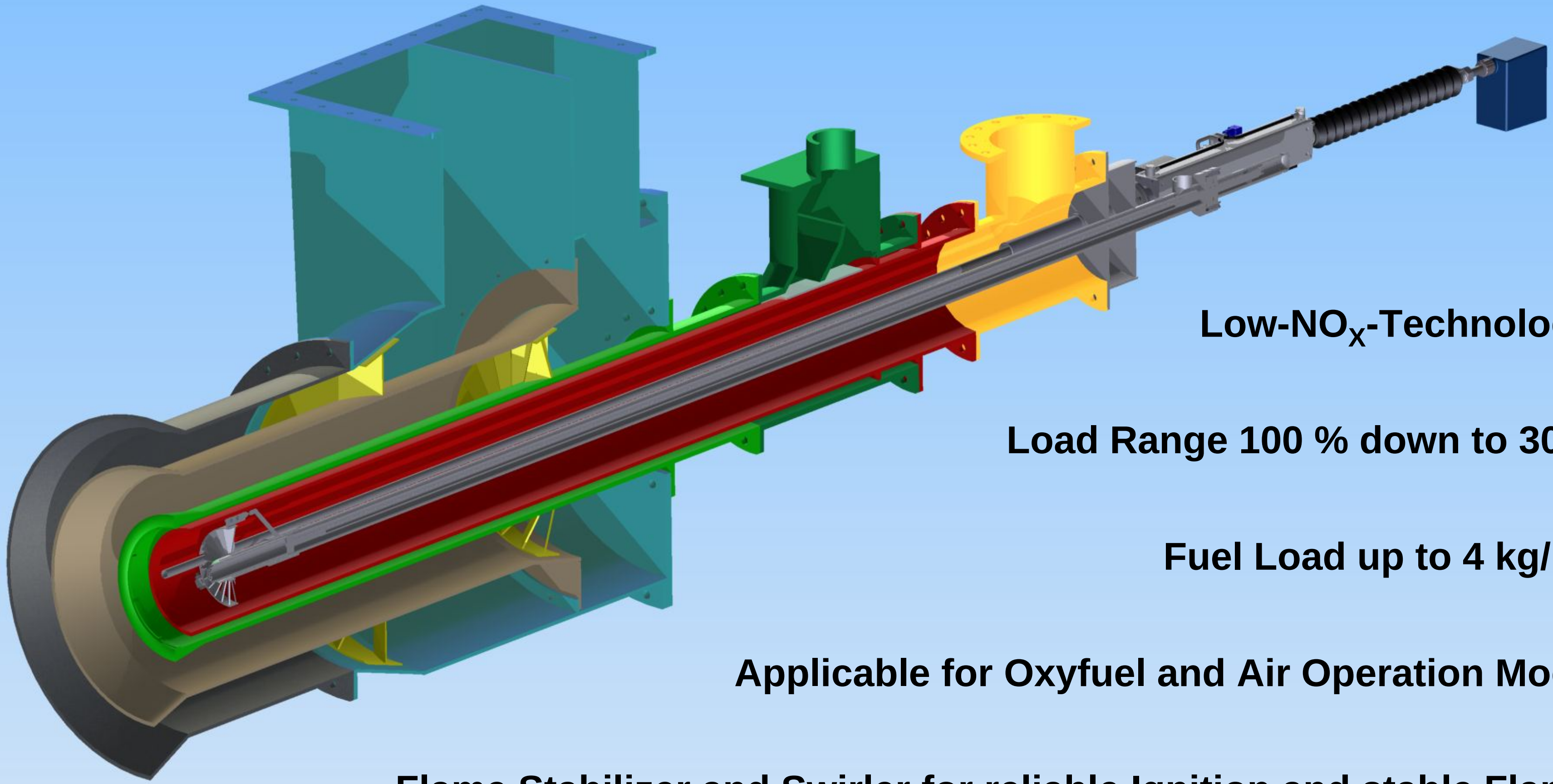
Features of OxyAir Burner 5



Low-NO_X-Technology

Load Range 100 % down to 30%

Fuel Load up to 4 kg/kg

Applicable for Oxyfuel and Air Operation Mode

Flame Stabilizer and Swirler for reliable Ignition and stable Flame

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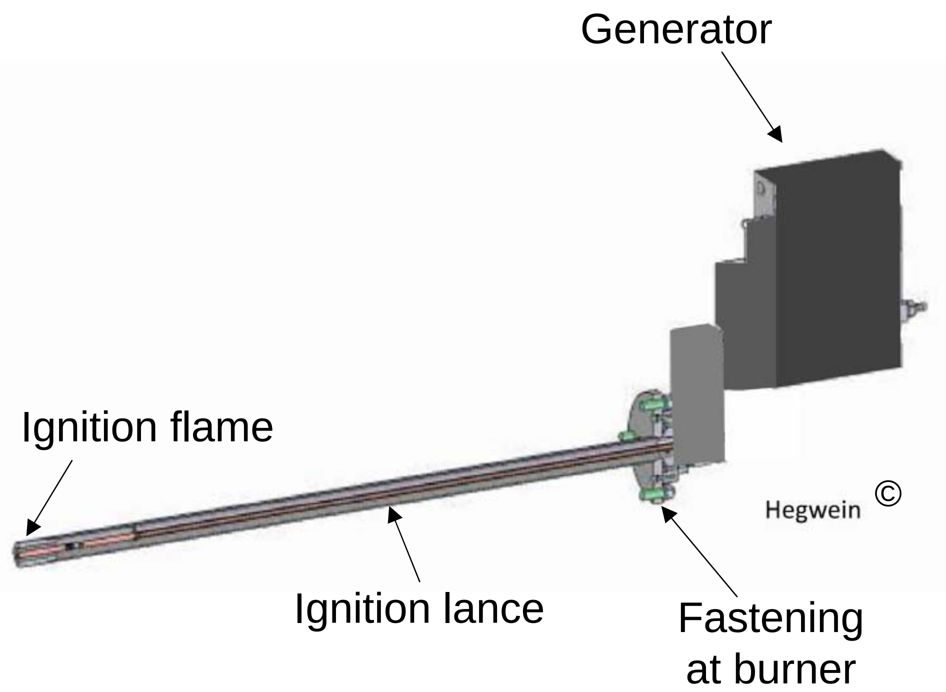
Test of ignition by Microwave-Plasmatron

Microwave- Plasmatron:

- No electrodes that could wear, low afford of maintenance
- Easy construction
- Low power consumption for ignition
- Technology is in development, currently no commercial solution available
- Limited in size
- Due to high temperature of plasma flame an external cooling is required



Concept:

- Direct Ignition of dried lignite by Microwave Plasmatron
- Usage of up to 3 plasma lances for ignition during tests operation
- Control of ignition by control box on-site
- Supply of external media e.g. power, compressed air and cooling water

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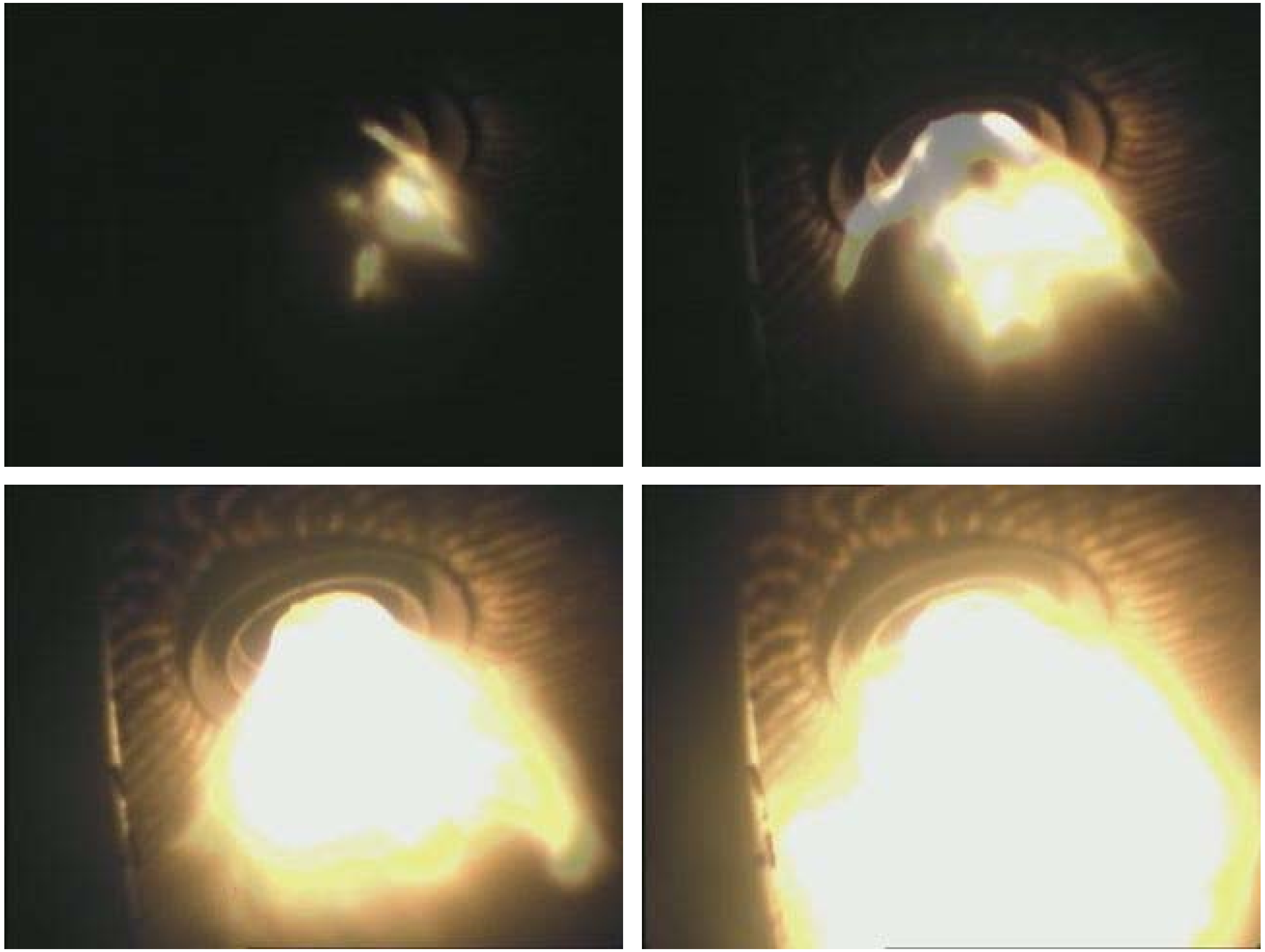
Ignition of 30 MW dry lignite burner with plasma lances



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Test results electrical Ignition

Criteria	Target	Actual	Comments
Number of plasma lances	3 - 1	1	All major issues of optimization are carried out with one plasma lance
Position of plasma lance			Optimal position is dependent on burner design
Boiler temperature	Cold boiler	43°C	Successful ignition in cold boiler
Start up load of burner	15 MW	3 - 15 MW	Successful Ignition over a wide Range, lowering of start performance on 10% (3 MW)
el. load for ignition of plasma lance	3 kW	2 kW	Successful Ignition with 2 kW el. Load
Temperature of combustion air	Without pre-heating	30 °C	Successful ignition without preheating of combustion air
Long term experience		> 100 Start	Get more information about ignition behaviour after long term deposition in boiler

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Summary and outlook

- Vattenfall cooperated with many technology partners for the burner development for Oxyfuel (5 burners from 4 different manufactures)
- Varified stable ignition and burnout behaviour
- Stable operation with high O_2 concentration in oxydant and low O_2 excess. All emission limits are reached.
- Pre-mixed mode for commercial CCS plant sufficient
- Burner design depends on firing concept
- Electrical ignition burner is an economical alternative

➔ Vattenfall is ready to scale up for a demo plant

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Thank you for your attention!