Experimental Testing of Oxy Combustion in a Pilot Scale CFB Boiler

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Outline

- Background of the study
- Oxy combustion
- Pilot process with Circulating Fluidized Bed (CFB) technology
- Test period, aims and test types

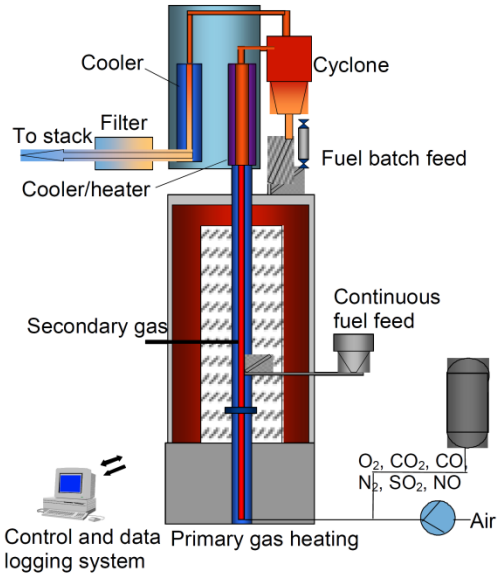
→ To be continued in the next presentation

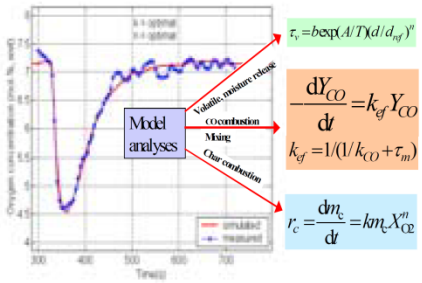
Background of study

- Oxy combustion development at VTT and Foster Wheeler
- Pilot scale CFB (circulating fluidized bed) boiler at VTT, Jyväskylä, Finland – air firing and oxy firing
- Foster Wheeler's FlexiBurn™ CFB combustion technology
- Studying oxy combustion dynamics with the aim of developing and validating combustion controls
- Simulation studies
- Study continued in a larger-scale (CIUDEN 30 MW_{th}) unit

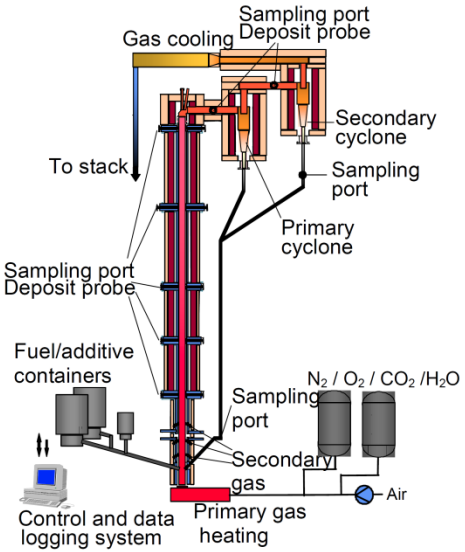
bench scale | **SCALE UP** **pilot scale** | **commercial scale**

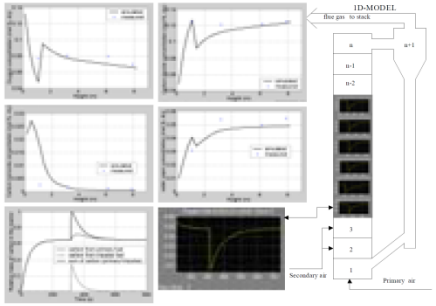
BENCH SCALE REACTOR (BFB/CFB)



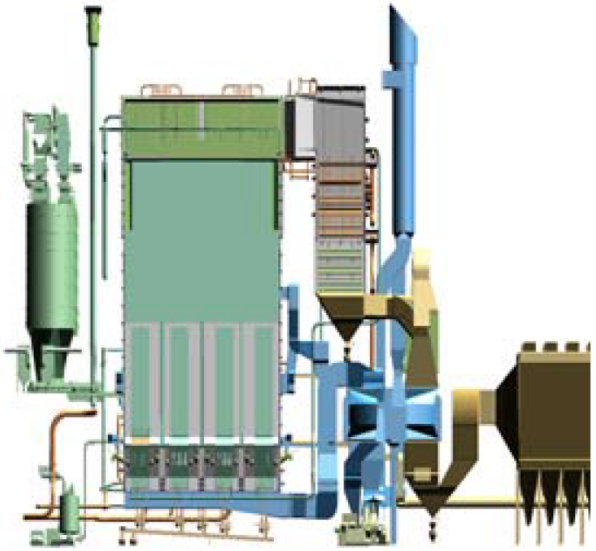


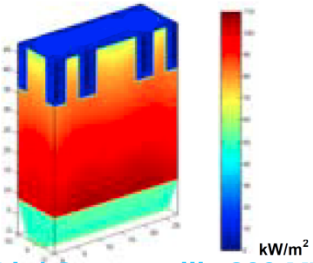
CIRCULATING FLUIDIZED BED REACTOR





ŁAGISZA 460 MWe supercritical OTU CFB





CIUDEN 30 MWth / Compostilla 300 MWe oxy-CFB projects

0D dynamic/stationary models | **MODELING TOOLS** **0D dynamic/stationary models** **1D dynamic/stationary models** | **1D design model** **3D model**

Oxy combustion

- Fuel burnt with oxygen (and inert flue gas) instead of air
  - result: flue gases very high in CO_2
- In demonstration phase
- Motivation: CO_2 mitigation in power plants

- **CCS - CO_2 capture and storage**
  "separation of CO_2 from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere" (IPCC 2005)
- Short and medium term solutions to the CO_2 issue in fossil power plants include CCS, increasing energy efficiency, cofiring with / switching to CO_2 neutral fuels

- Oxy combustion
- Post-combustion capture
- Pre-combustion capture
- Chemical looping

Oxy combustion – changes in gas composition and properties

		Gas constituents, % (wet basis)	
		Combustion with air	Combustion with O_2
Windbox	O_2	21	21–30
	N_2	79	0–10
	CO_2	0	40–50
	H_2O	small	10–20
	others	–	NOx, SO_2
Flue gas	O_2	3–4	3–4
	N_2	70–75	0–10
	CO_2	12–14	60–70
	H_2O	10–15	20–25
	others	NOx, SO_2,	NOx, SO_2

- Oxygen (purity 95-99%) produced in an air separation unit, mixed with recycled flue gas (RFG)
- Oxidant gas contains little N_2, high amounts of CO_2 and H_2O
- Significantly higher gas density and heat capacity
- In oxy combustion, the oxygen amount is not limited to 21 vol-%
- Different oxidant flows may have different O_2 content

(Davidson & Santos 2010)

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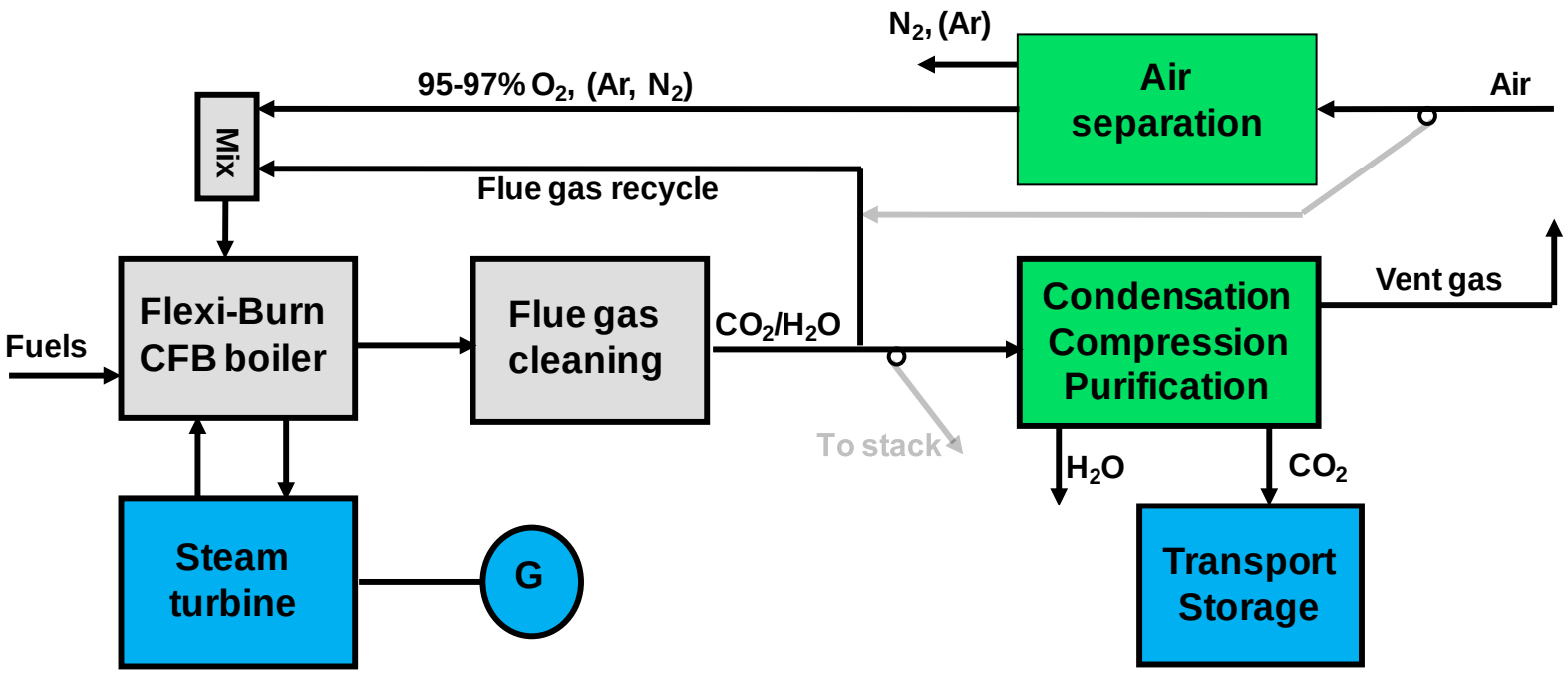
Air and oxy combustion in the same boiler: Flexi-Burn™



- Air and oxy firing can be used in the same CFB boiler
- Approximately the same conditions for both firing modes
- Dual firing enhances flexibility

The pilot CFB test rig at VTT

- Fuel power 50-100 kW in oxy mode, 20-50 kW in air mode
- Siemens PCS7 automation system

- Two fuel containers
- Containers for limestone, sand and other additives
- Primary gas fed through the grid, secondary gas added at different levels
- Gas flows and compositions can be adjusted independently for primary and secondary gases
- Oxidant gas consists of air, bottled O_2, RFG, CO_2, N_2
- Flue gas recirculation system (fan with flow measurement and control)

- Several separately controlled electrically heated and water/air cooled zones
- Extensive temperature and pressure measurements
- Flue gas composition measured by FTIR spectrometer and traditional on-line gas analyzers
- Gas and solids sampling ports, bottom ash discharging

Test period with the CFB pilot

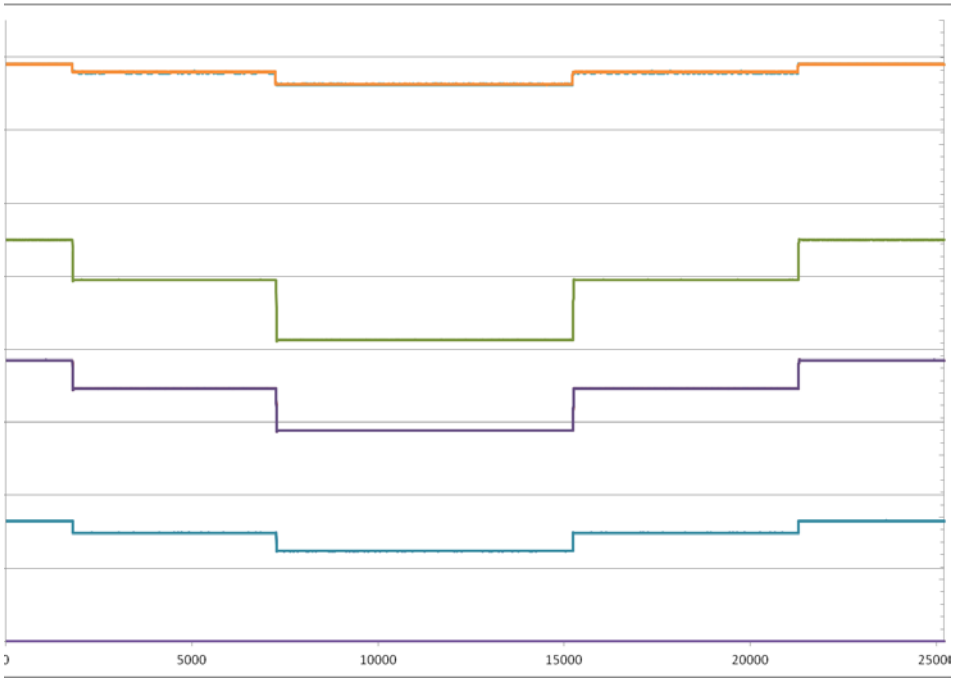
- Dynamical behaviour needed for control design
- Finding the best operation procedures

- Test matrix was designed to reveal the essentials in boiler dynamics
  - Load steps AIR, OXY
  - Load ramps OXY
  - Switches AIR-OXY, OXY-AIR

- Output measurements of interest: gas compositions, flue gas O_2, furnace pressures, temperature profiles and dynamic behaviour...

Load steps

- Air: 100 → 90 → 75 → 90 → 100 % load
- Oxy: 100 → 85 → 70 → 85 → 100 % load



Fuel feeding screw, rpm

Total gas (air) flow, Nl/min

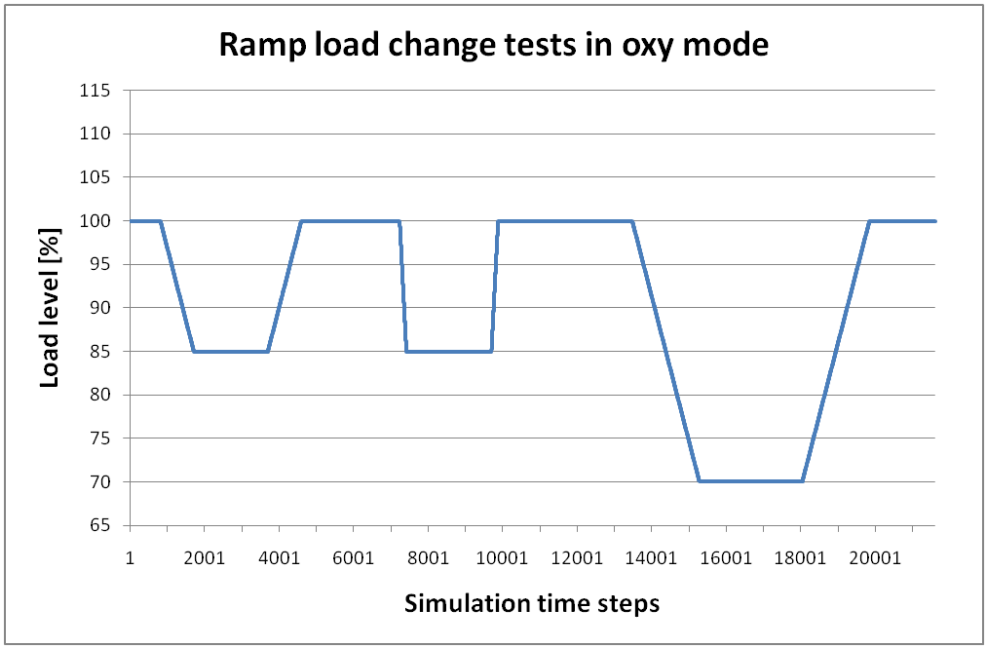
Primary air, Nl/min

Secondary air, Nl/min

- stepwise simultaneous changes in fuel and gases

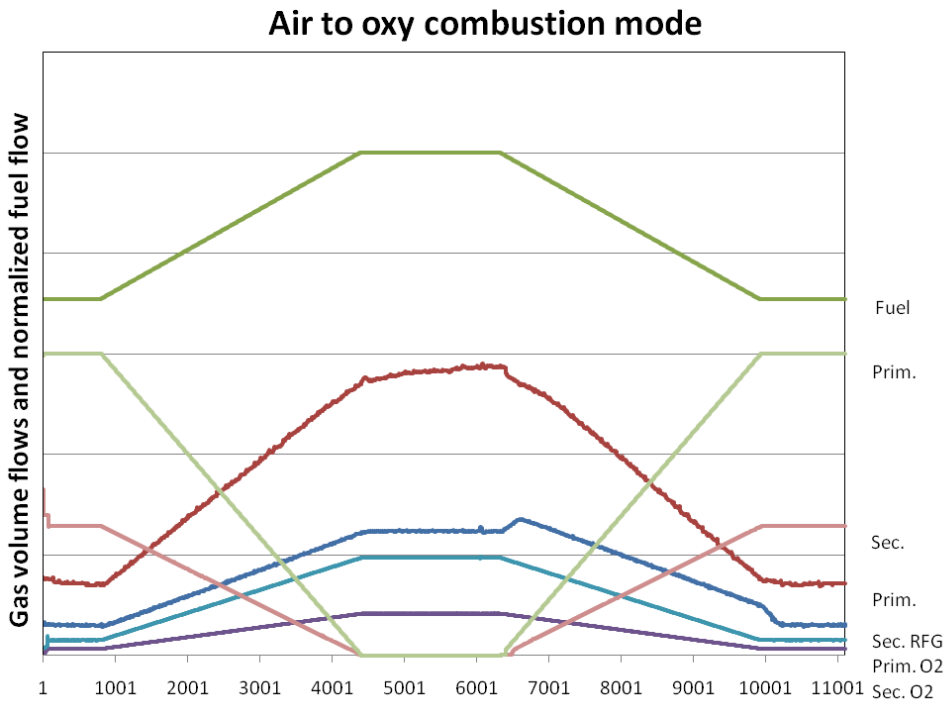
Load ramps in oxy combustion mode

- Slow ramp 1%/min -> 15% change
- Fast ramp 5%/min -> 15% change
- Slow ramp 1%/min -> 30% change



Combustion mode switch: air-oxy, oxy-air

- Straight from air (O_2 21 vol-%) to oxy mode (O_2 28 vol-%), keeping fluidization constant
- Simultaneous load change



Further studies

- A hot-loop (furnace) simulation model developed to be validated based on the measurement data
- Current study will be continued in a larger-scale (CIUDEN 30 MW_{th}) unit.

Modified from: http://www.vtt.fi/files/sites/flexiburncfb/flexiburncfb_poster.pdf