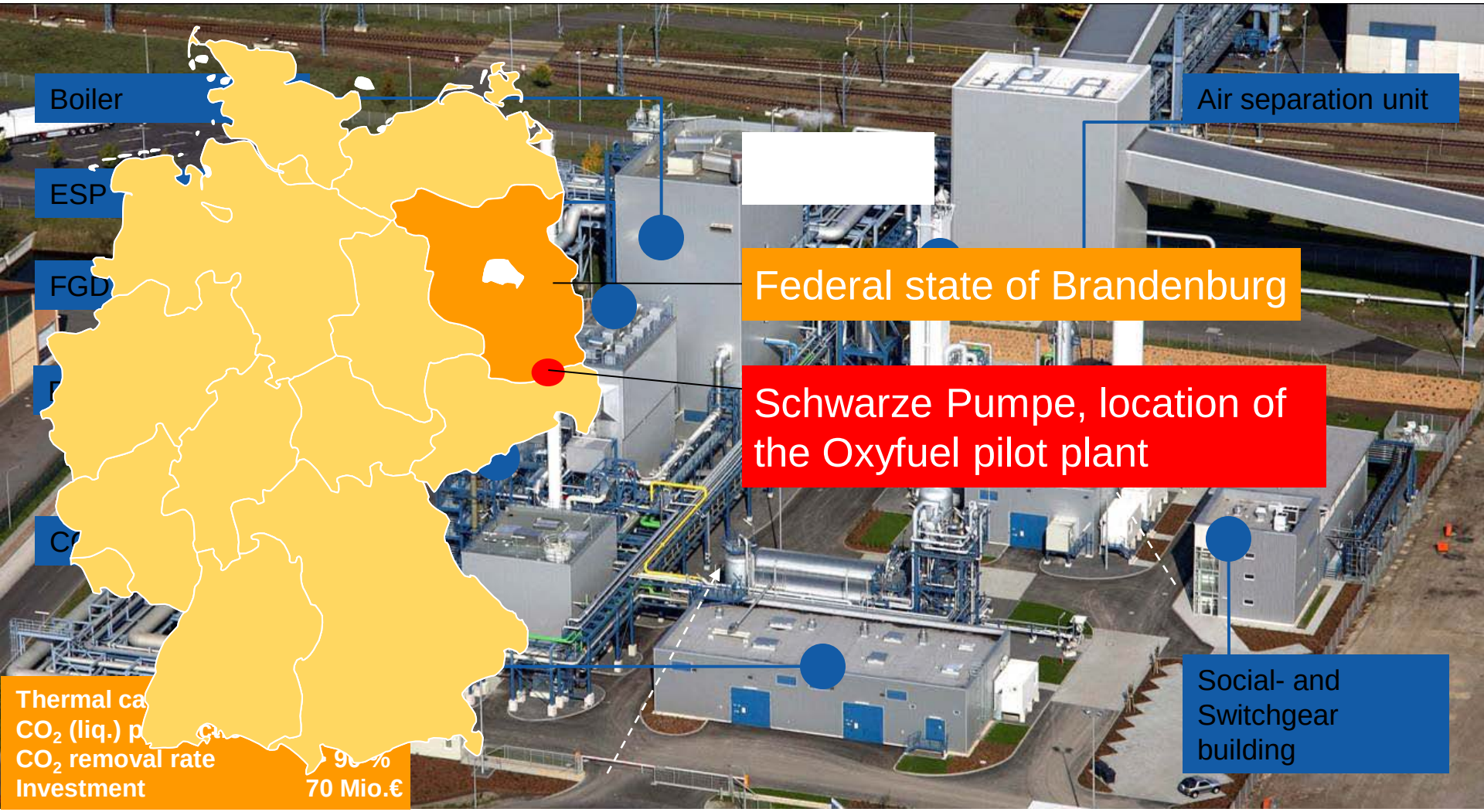
Corrosion in an Oxyfuel boiler – First results from Vattenfalls 30MWth Oxyfuel Pilot Plant in Schwarze Pumpe

IEAGHG Special Workshop on SO2/SO3/Hg/Corrosion Issue under Oxyfuel Combustion Conditions, January 2011, London

Alexander Gerhardt Anders Hjörnhede, Melanie Montgomery, Martin Bjurman and Pamela Henderson

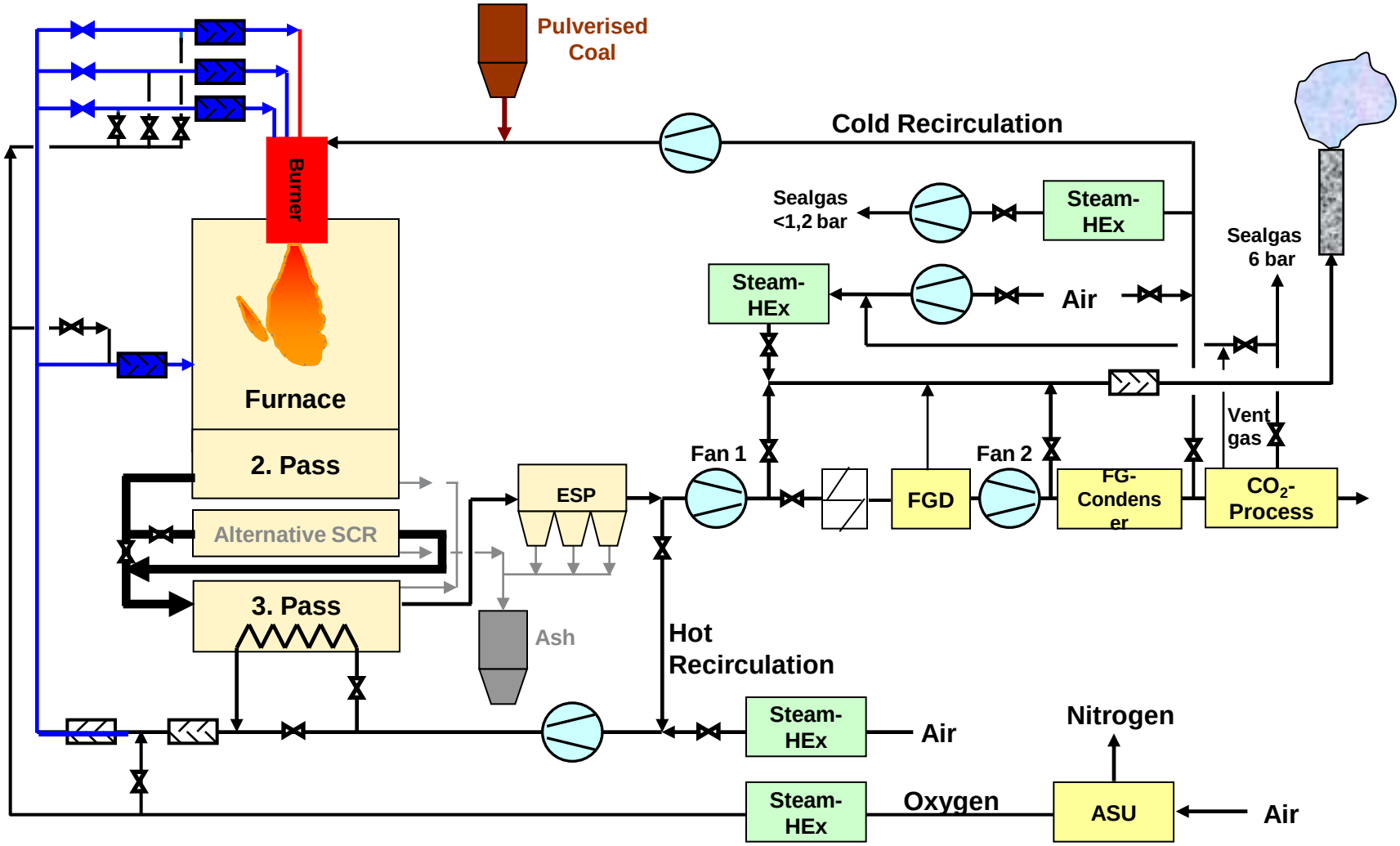
- Introduction
- Furnace measurements
- Material tests
- Future

The Oxyfuel Pilot Plant in Schwarze Pumpe (Germany)



VATTENFALL

Plant overview- the Schwarze Pumpe OxPP



VATTENFALL

Furnace measurements

Main focus for furnace measurements and operation points

- To quantify differences between air and oxyfuel operation and between different oxyfuel operation cases in pilot scale regarding
  - Combustion performance
  - Heat transfer
  - NO_x formation

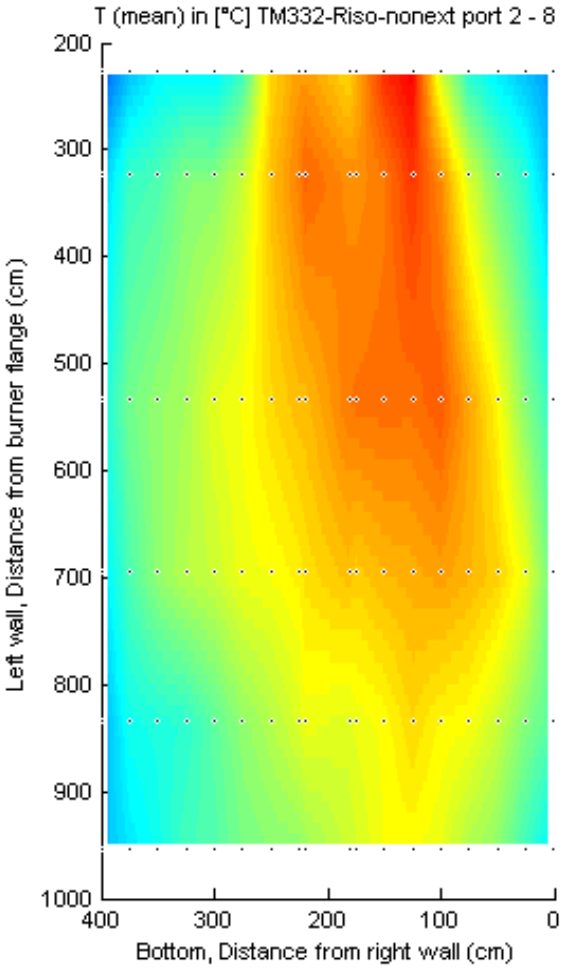
		AIR	OXY25	OXY30
Steam load	[MW]	27,0	27,0	25,9
Fuel load	[MW]	29,1	27,6	26,4
O_2-concentration in oxidant	[%, wet]	air	25,0	30,4
O_2 (in flue gas)	[%, wet]	2,8	3,4	3,2

- The fuel fired was a Lausitz Lignite, with about 6 % ash on dry bases, a water content of 10% and a lower heating value of approximately 21MJ/kg.

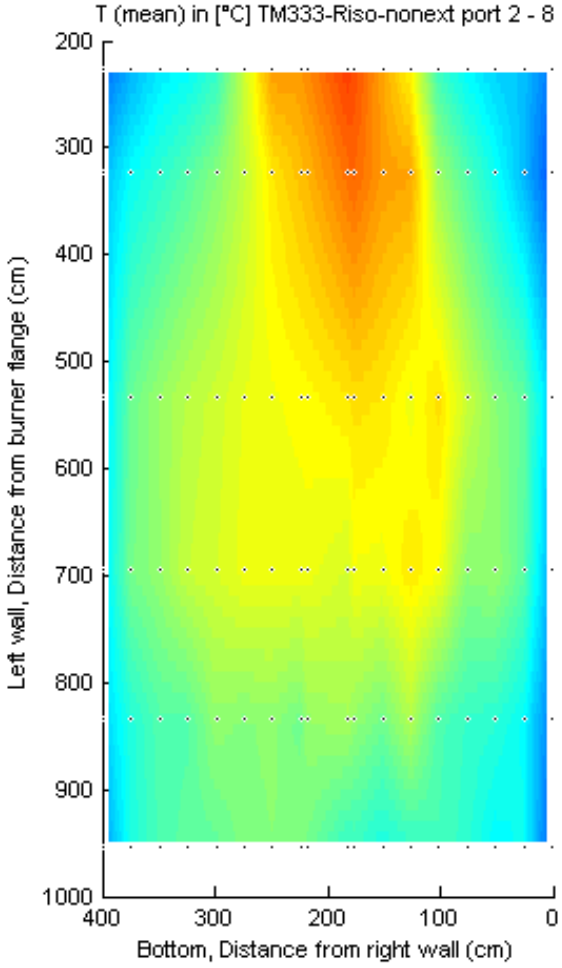
VATTENFALL

Flame shape – Temperature [C] (FTIR)

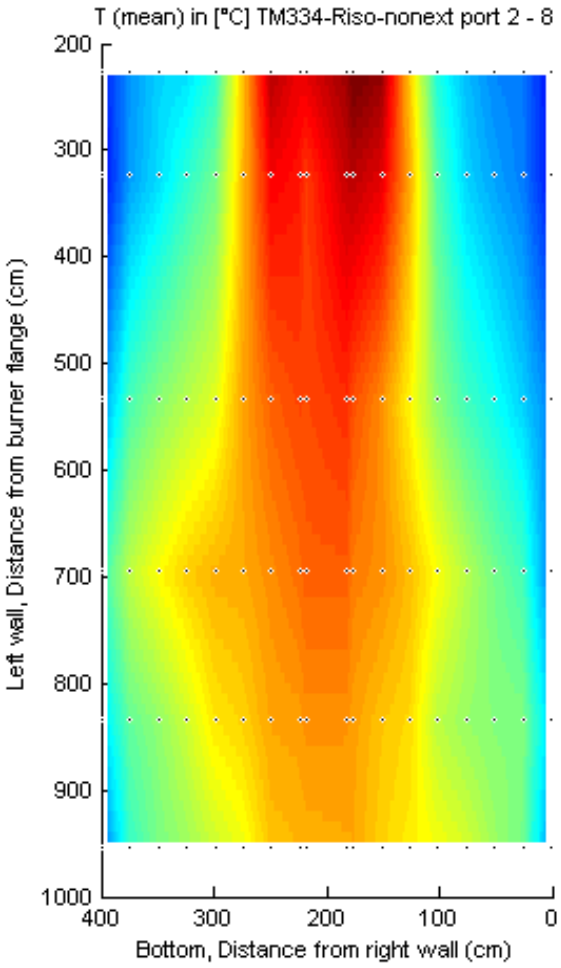
AIR

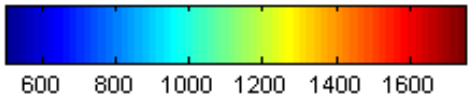


OXY25



OXY30

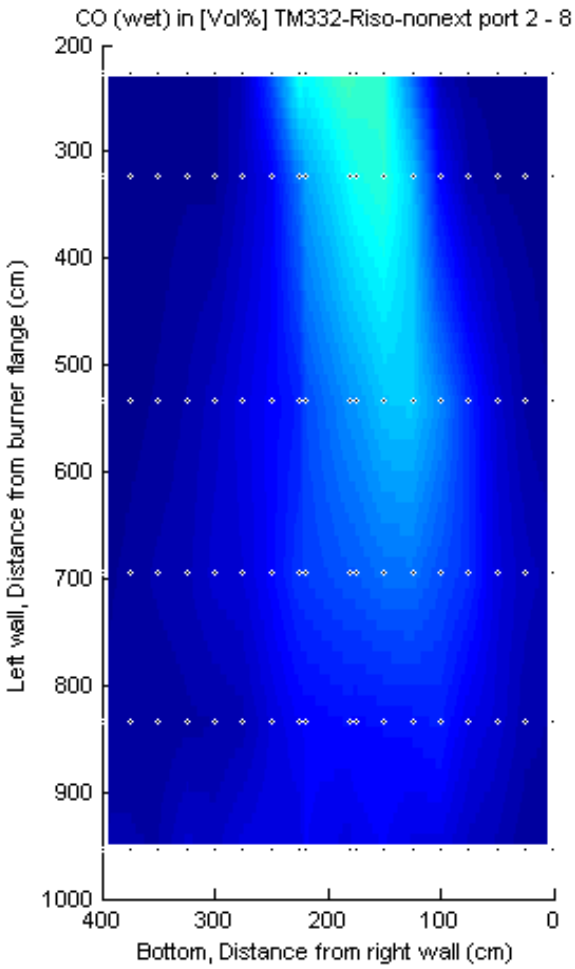




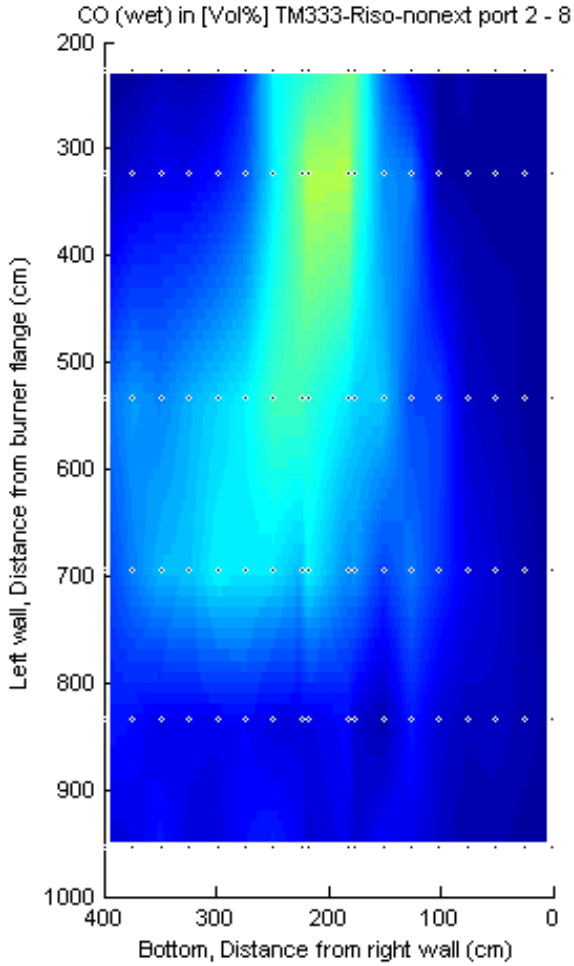
VATTENFALL

Flame shape – CO [vol%, wet basis] (FTIR)

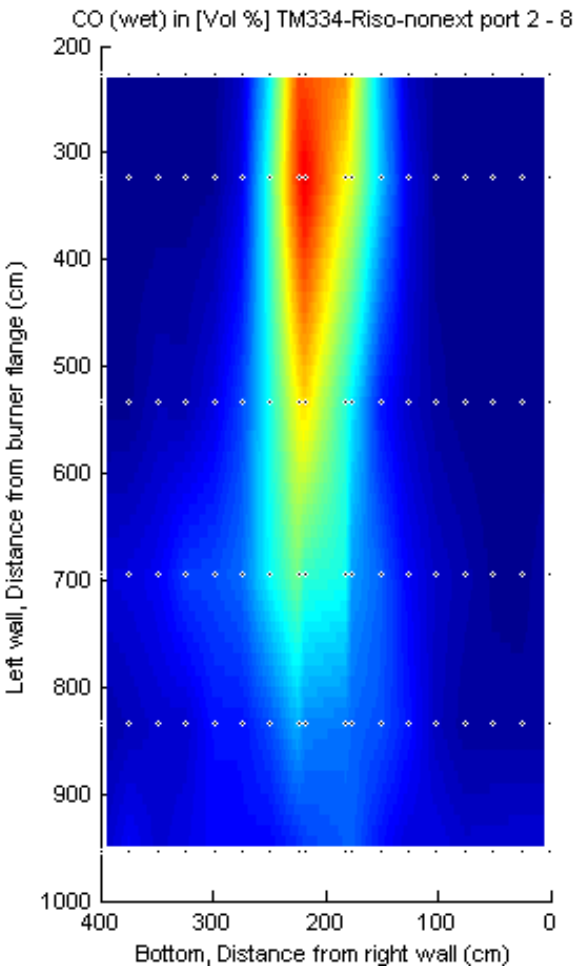
AIR



OXY25



OXY30



VATTENFALL

Material tests

Corrosion and Material testing in OxyFuel environment

- Are the corrosion rates and corrosion mechanism same as in conventional coal fired boilers?

- Exchange $CO_2 \Leftrightarrow N_2$
- Carburisation
- Influence the heat transfer from flue gas to heat absorbing surfaces

- Risk of enrichment of corrosive species (recirculation)
- More corrosive flue gas and condensates will form
- Both oxyfuel- and air fired modes must be handled

- Higher power plant efficiency with super austenitic steels or Ni-based materials

- Specific objective: Materials for Demo Plant

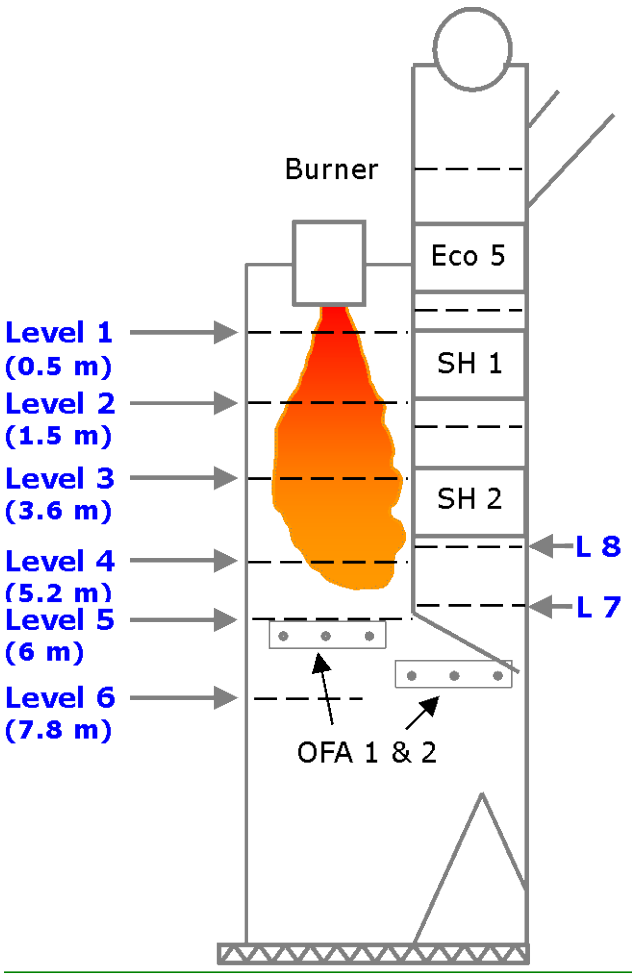
Purpose

Identify useful materials for (screening):

- Super heater at 650 C metal temperature
- Super heater at 580 C metal temperature
- Super heater at 750 C metal temperature
- Economisers
- Water walls
- Low temperature corrosion (70 – 170 C)

- *ESP, FGD, FGC, recirculation duct, etc*

- Analysis of deposits formed on super heaters (ash formation)
- Identify differences between conventional coal firing and oxyfuel firing



VATTENFALL

Flue gas composition and fly ash

Flue gas measurements after ESP (wet) for Oxyfuel

- CO2 ~ 65% and O2 < 4 %
- SO_2 ~ 7000mg/m³ (Air ~ 1600mg/m³)
- H_2O ~ 27-29% (Air ~ 8%)
- CO < 200 mg/Nm³, NOx < 500 mg/Nm³

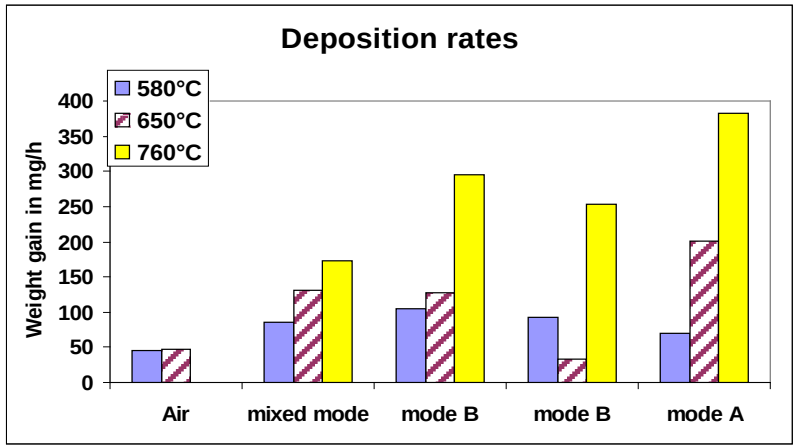
Corrosive species SO_2 and H_2O approx 4 times greater in oxyfuel.

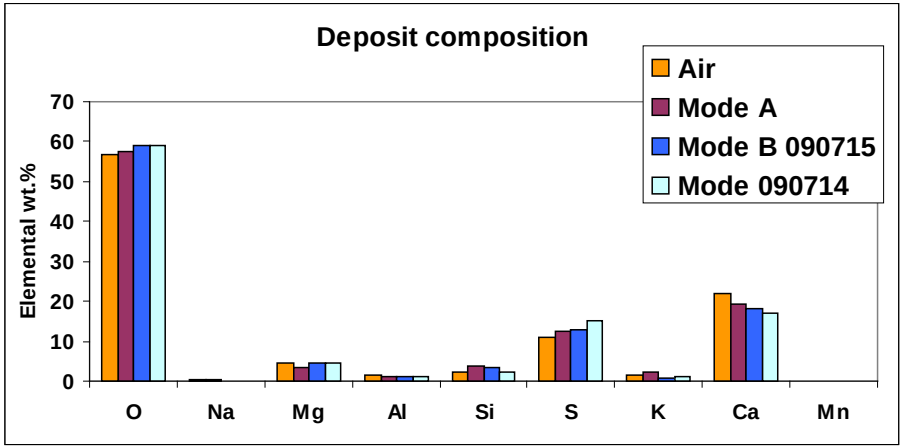
- SO_3 in fly ash
  - Air SO_3 46 $\pm$ 9 (mg/kg)
  - Oxyfuel SO_3 77 $\pm$ 18 (mg/kg)
- Otherwise ash composition is similar

VATTENFALL

Deposit probes

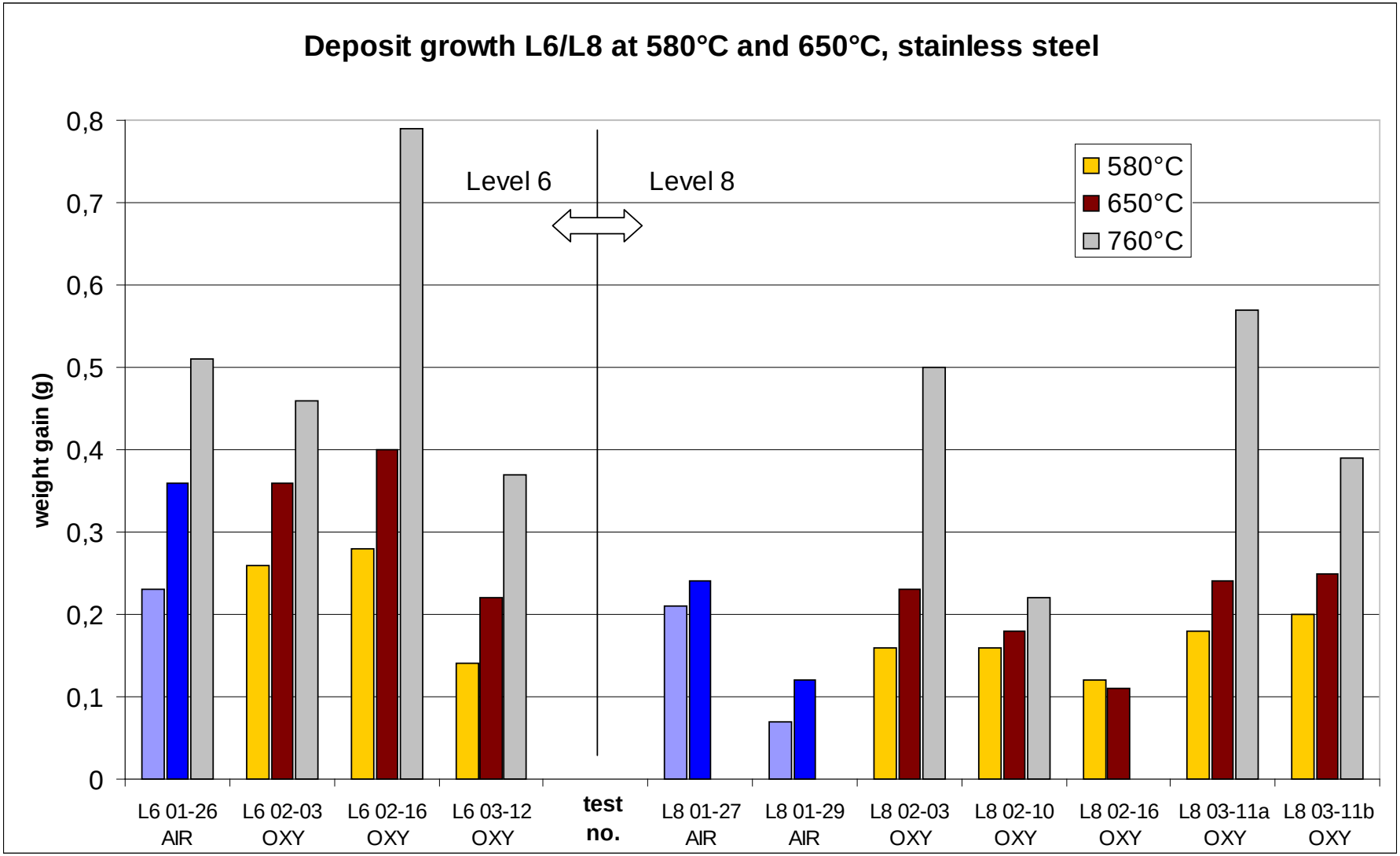
- Deposit probes were exposed at different metal temperatures.
- Indication of increased deposition with higher temperatures, but this requires further investigation.
- Greater variation in the different oxyfuel modes than between air-firing and oxyfuel.
- Analysis of deposits with SEM-EDS reveals that the elemental composition is similar for both oxyfuel and air-firing deposits.





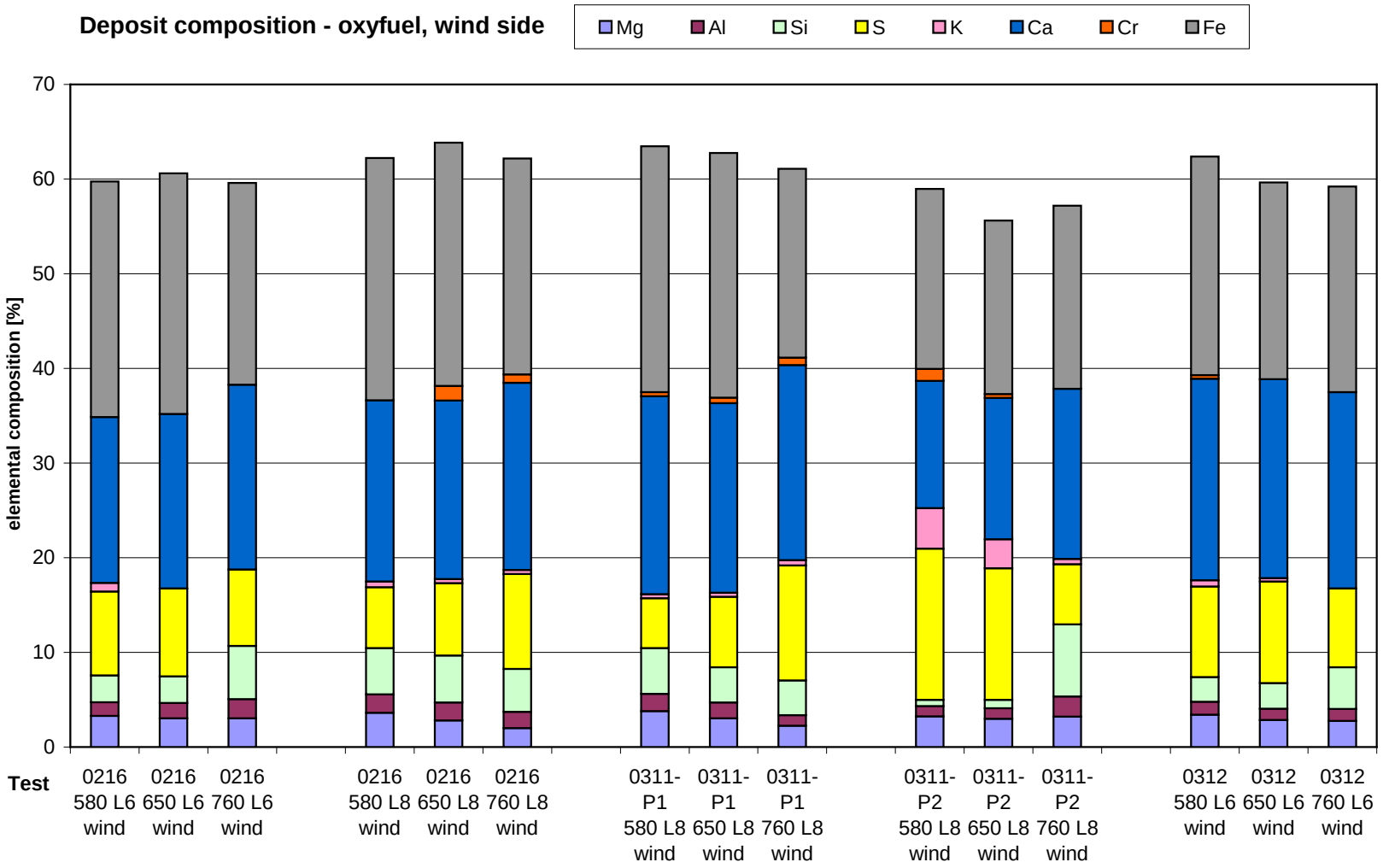
VATTENFALL

Deposit weight gain



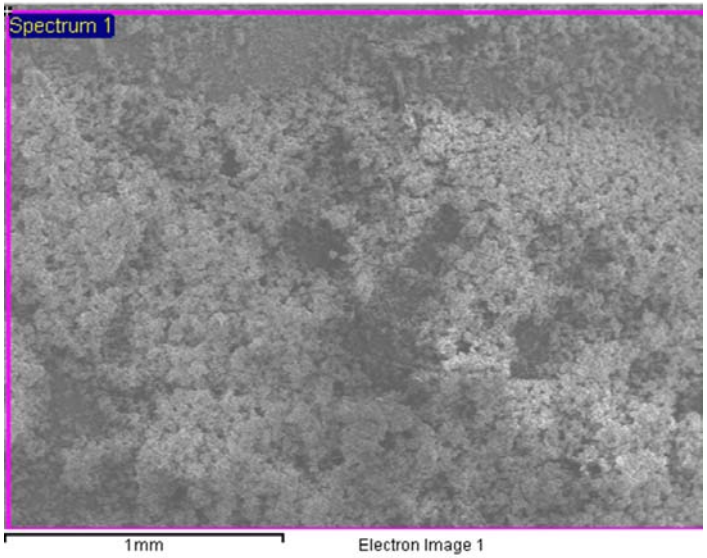
VATTENFALL

Deposit under Oxyfuel

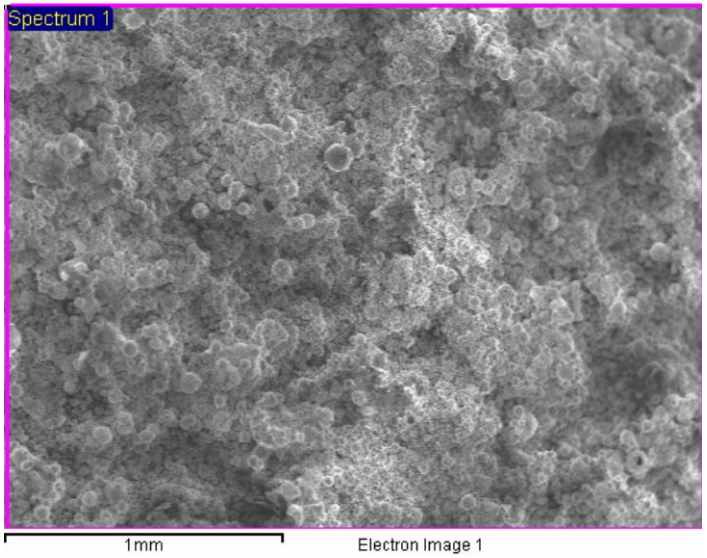


VATTENFALL

Oxyfuel deposit morphology



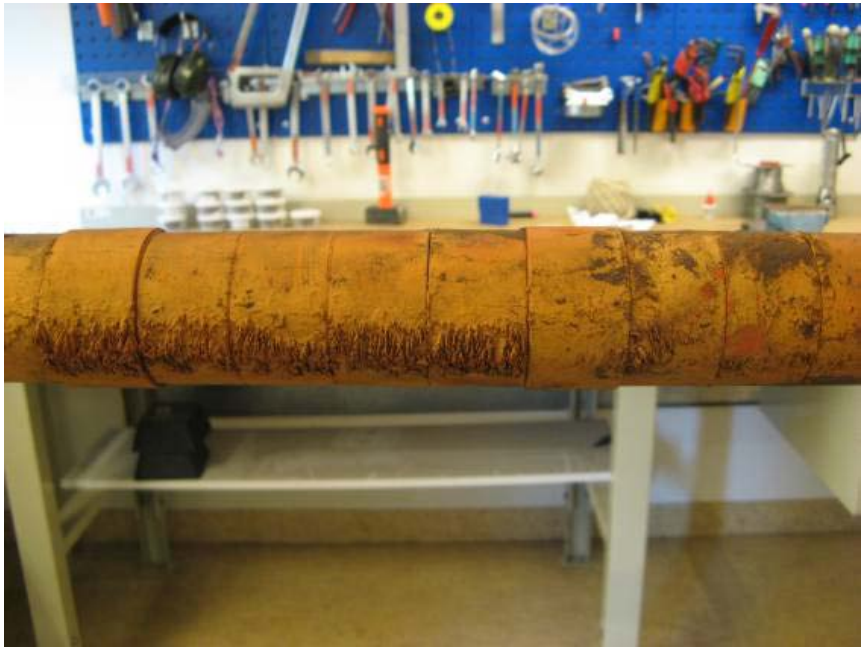
L 8 16 Feb. Windward side 650ºC. Substrate can be seen under deposit



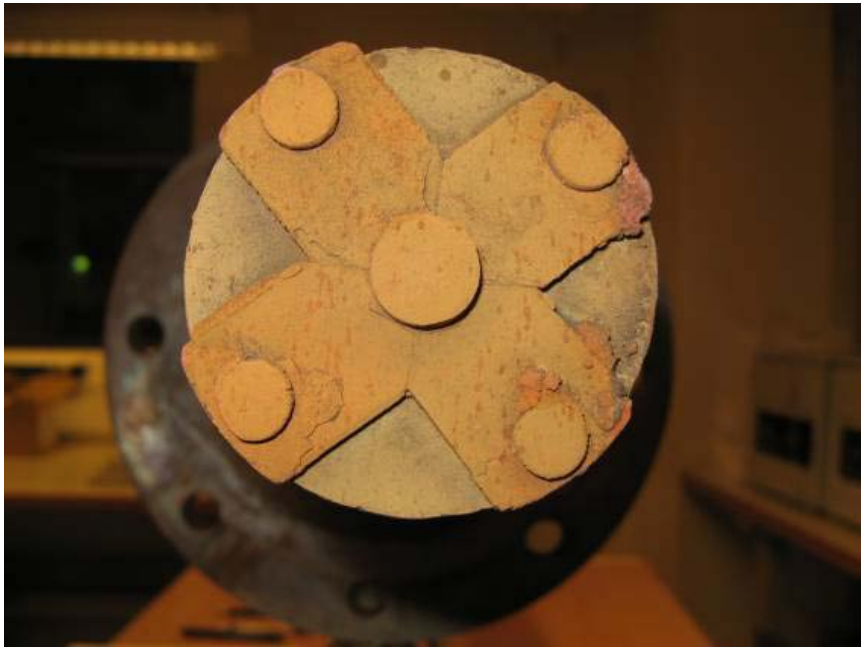
L6 16 Feb. Windward side 650ºC. Thick deposit covering substrate

VATTENFALL

Corrosion probes after exposure in plant



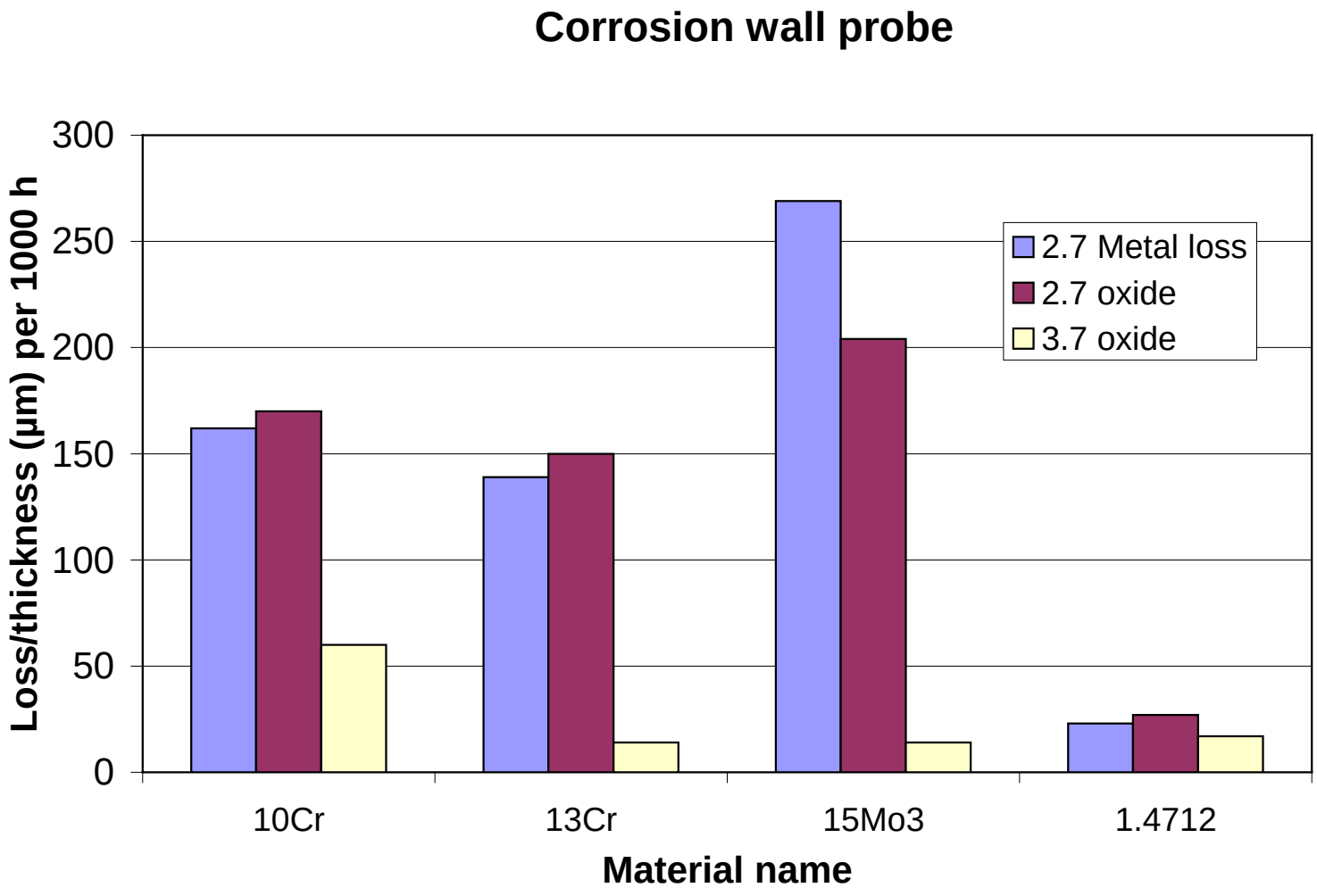
Super heater probe (580°C)
separated with isolators



Wall probe, flush mounted
4 coupons

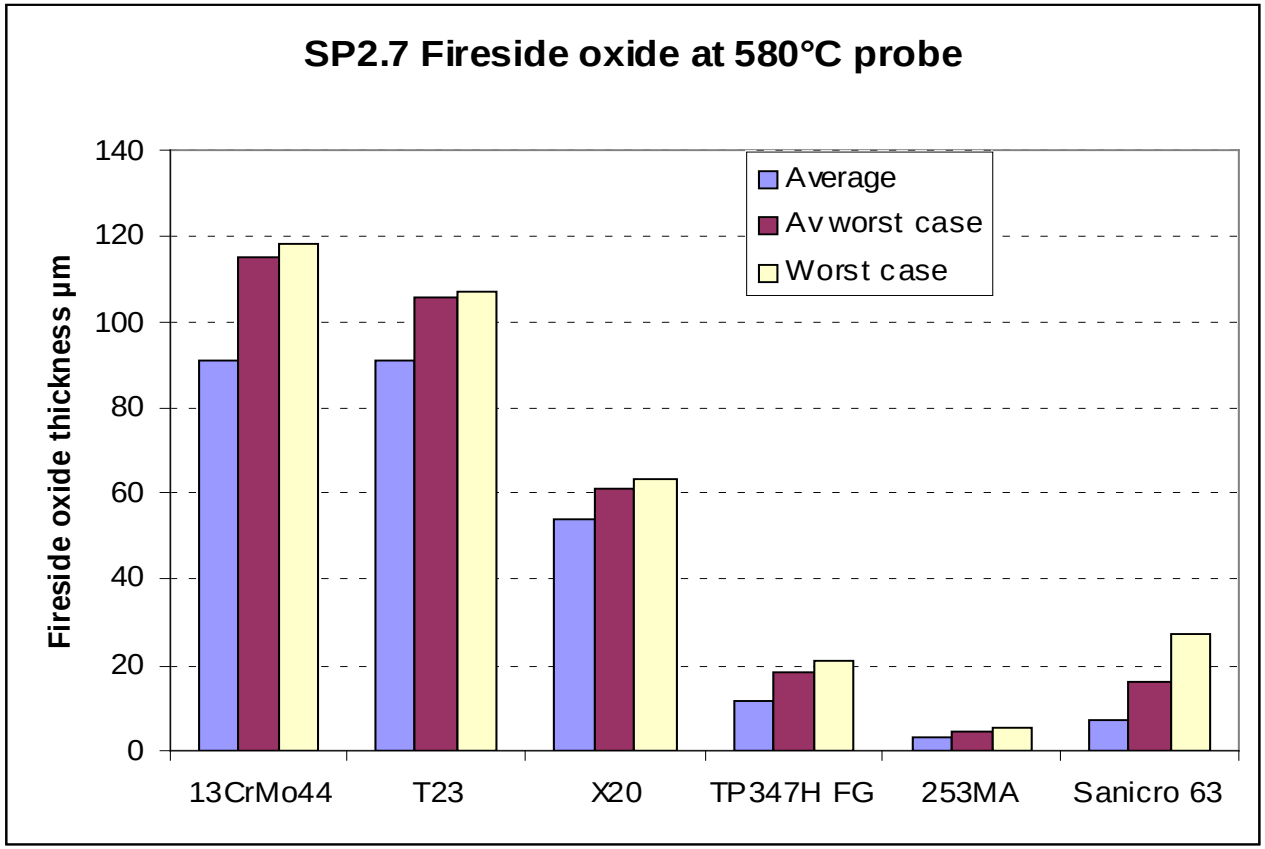
VATTENFALL

Wall corrosion probe



VATTENFALL

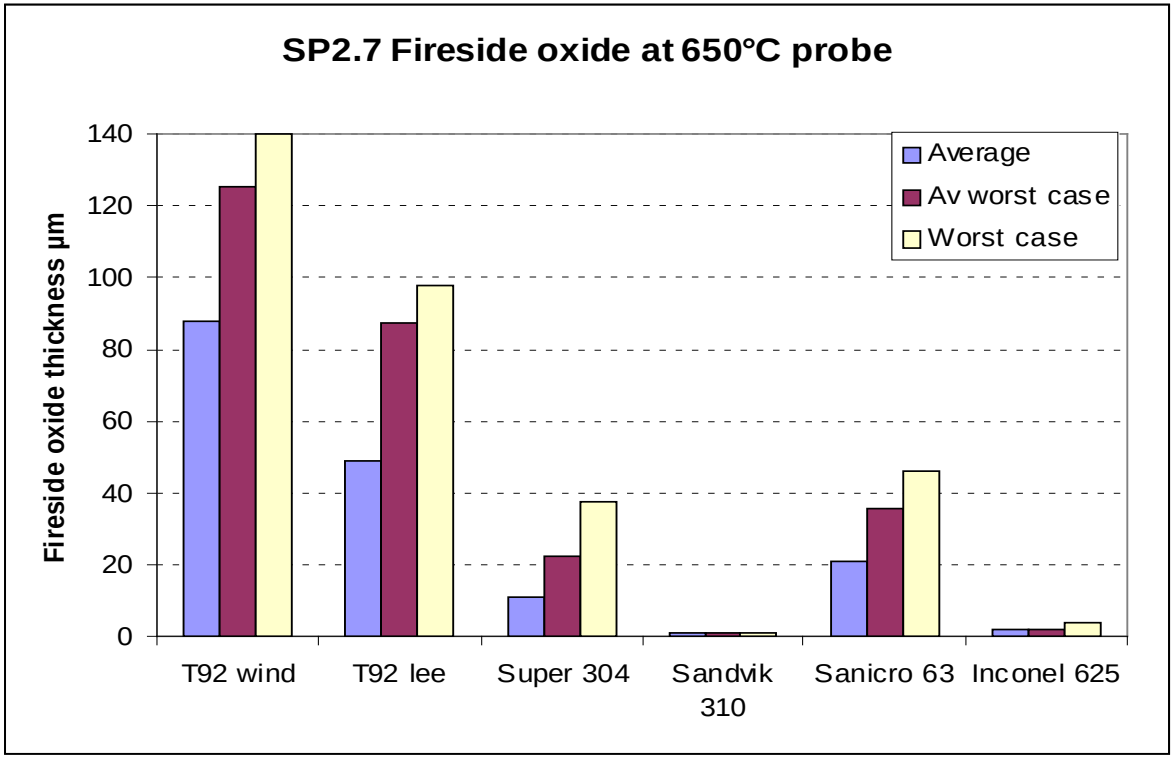
OxyFuel: Oxide thickness after 1300 hrs



Sanicro 63 (Alloy 625), 347H FG and 253MA perform well at 580 C.
10Cr and T23 no good performance and X20 at the border

VATTENFALL

Oxide thickness after exposure at 650 C



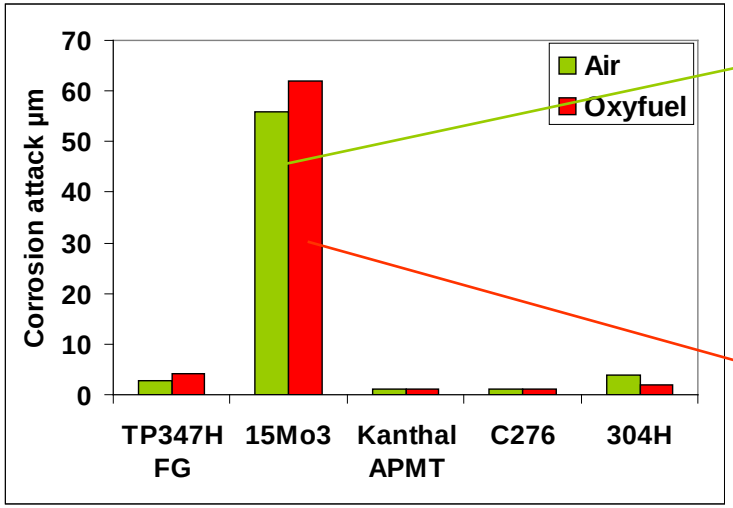
AC66, TP 310, 304H and T92 showed no good perfomance at 600 C steam in oxyfuel.

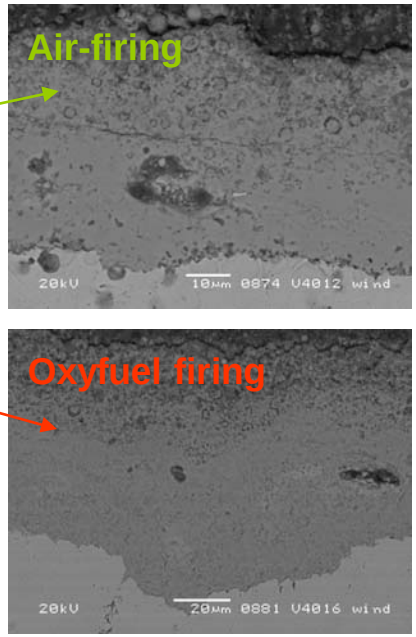
Questions about Sanicro 63 and Alloy 625?

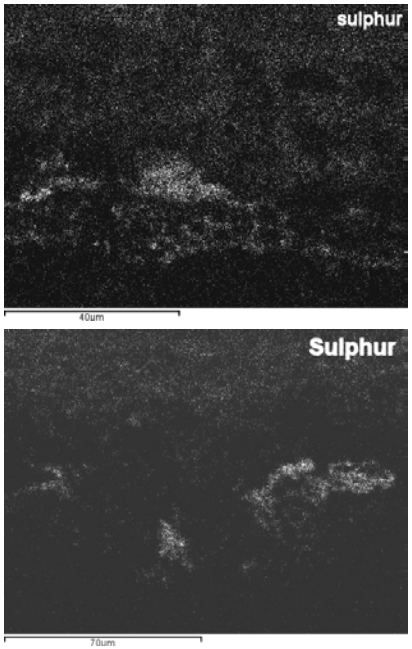
VATTENFALL

High temperature corrosion probes (e.g. 580C)

- No significant difference between the air-firing and the oxyfuel firing mode.
- SEM-EDS analysis revealed similar corrosion morphologies in air and oxyfuel, e.g. sulphur
- There was no sign of increased carburisation due to the higher CO_2 concentration in the gas phase, maybe due to the similar oxygen content
- Problems with carburisation could occur on the waterwalls due to low oxygen stoichiometry.

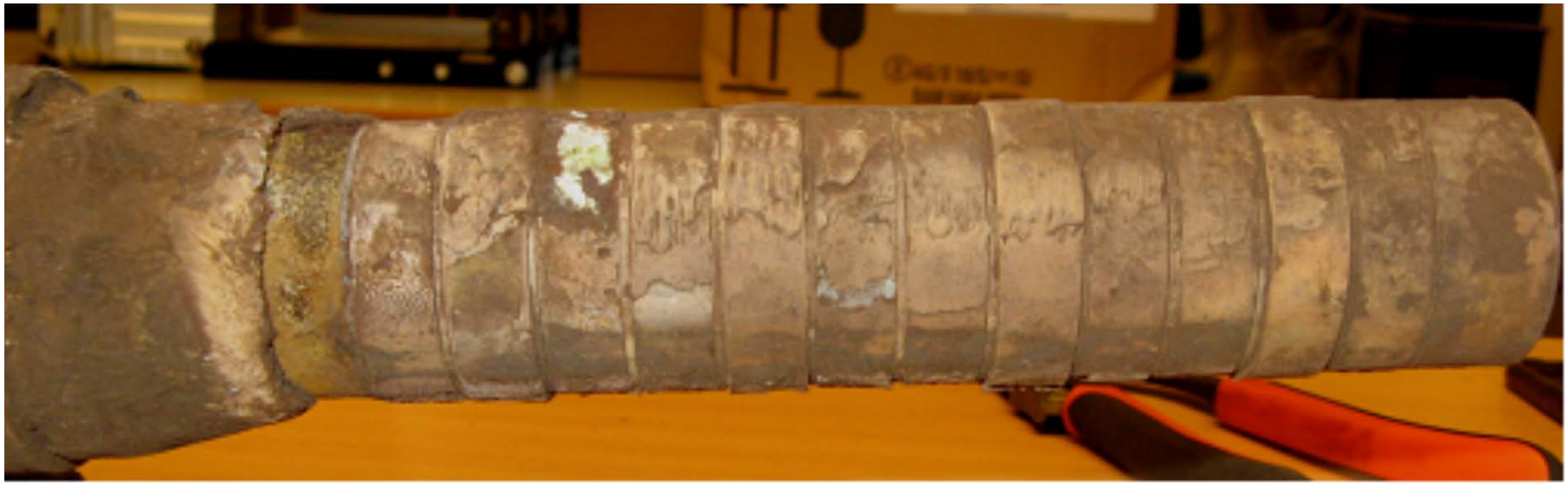






VATTENFALL

Low temperature gradient probe

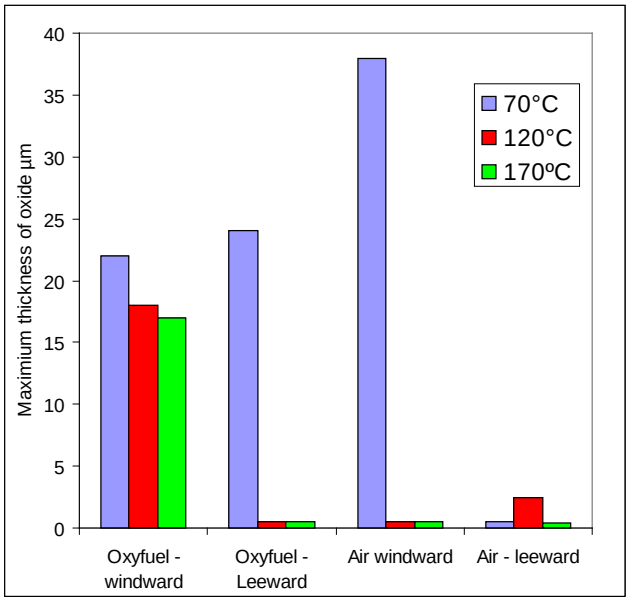


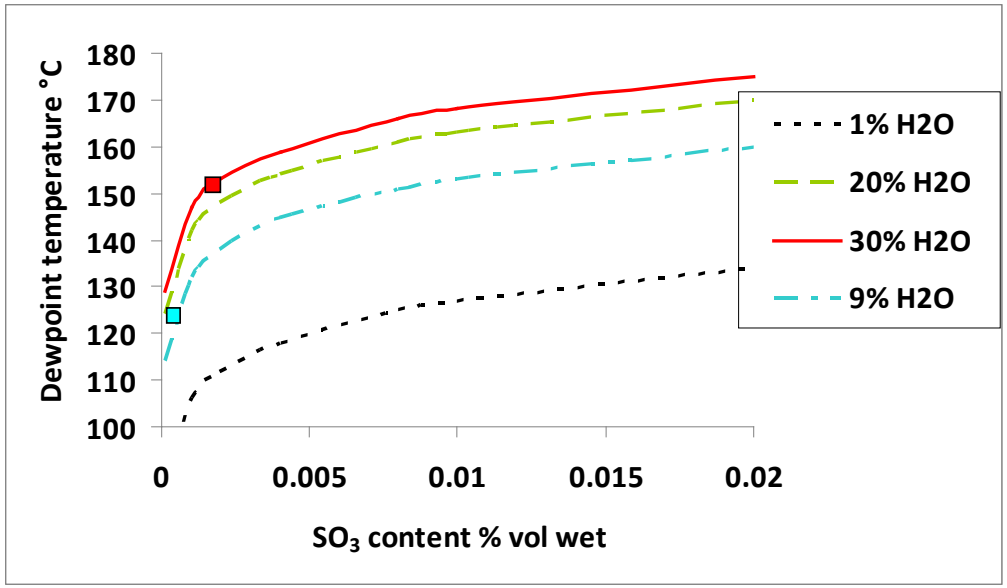
Corrosion probes after exposure in plant

VATTENFALL

Low temperature corrosion probes

- 15Mo3 sustained corrosion over a wider temperature range in the oxyfuel mode
- The deposits on the probes for oxyfuel firing were enriched in sulphur especially at 170 C. Calculations show that the acid dewpoint due to the increased presence of SO_3 is about 30 C higher in the oxyfuel mode.
- In addition the increase in water content from 9% to 30% also increases the dewpoint temperature.





VATTENFALL

Summary on material tests

- Strong indication of higher material wastage rate in OxyFuel
- Deposit composition and corrosion attack on high temperature components were similar
- The temperature range where low temperature components are susceptible to corrosion has increased due to oxyfuel firing probably due to increased susceptibility to SO3 dewpoint corrosion.
- There may be more ash deposition in the oxyfuel mode.

- Increased S-concentration in corrosion front
- Ni-based alloys may form non-protective NiO
- (Cu – containing alloys may form non-protective Cu-crystallites)
- Al-containing materials may form protective oxide (Al_2O_3) and is not getting carburised

- Carburisation (super austenitic steels, Ni-based) still under investigation

Future outlook

VATTENFALL

Roadmap for CCS

Concept-studies

Testrigs:
0.1 – 0.5 MW_{th}

Pilot plant:
30 MW_{th}

Demonstration plant:
≈ 300 MW

Commer. plant:
≈ 1000 MW

2001	2004	2008	2015	>2020
• theoretic Investigations	• Research • Basic principles • Combustion characteristics	• Demonstration of the complete process chain • Interaction of components • Validation of test rig results • Investigation of scale up criteria	• Verification und Optimisation of components • Reduction of risks • Verification of commercial availability (subsidies necessary)	• Economic and competitive power plant concept

VATTENFALL

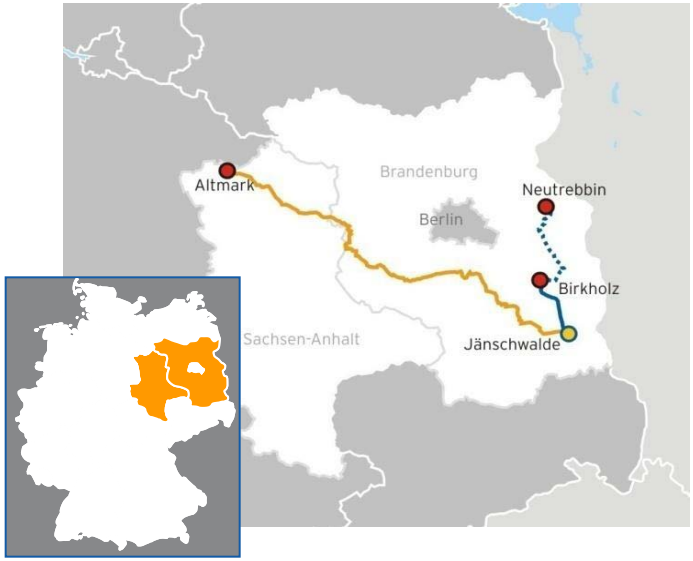
Demo plant Jänschwalde and potential storage sites

Separate new Oxyfuel block:
- 250 MW
- CO_2 removal > 90%
- 1.34 Mt/a separated CO_2

Retrofit Block F:
- PCC equivalent to 50 MW
- 0.39 Mt/a separated CO_2

Altmark:
EGR pilot project in cooperation with Gaz de France (pipeline 300 km)

Brandenburg (Birkholz or Neutrebbin):
Storage in deep saline aquifers (pipeline 50/140 km)



VATTENFALL


alexander.gerhardt@vattenfall.de