Decreased corrosion at high temperature?

Superheater corrosion testing in boilers

Oslo, 16 February

Annika Stålenheim, Vattenfall Research and Development

VATTENFALL

Vattenfall in brief

- Europe’s fifth largest generator of electricity and the largest producer of heat
- Operations in Sweden, Finland, Denmark, Germany, Poland, the Netherlands, Belgium and the UK with a total of 7.4 million electricity customers and 5.6 million network customers
- 39,000 employees
- Vattenfall AB is wholly owned by the Swedish state

VATTENFALL

Background, higher steam temperatures

- Vattenfall plans for a dramatic increase of the biomass use
  Much biomass can be co-combusted in coal power plants
- There will also be a need for dedicated biomass plants
- These plants should have high electrical and fuel efficiency to ensure cost-effective biomass use
- Vattenfall plans for at least 10 new bio-CHP plants

Increase the electrical efficiency

– Today: approx. 30-31% net electrical efficiency, 540°C/140 bar
  Potential: 36% net electrical efficiency, 600°C/190 bar
– The boiler is the most critical component (corrosion at superheaters and waterwalls)
- This requires the right choice of materials + additives

Corrosion testing within WP 2.4.3

- Two corrosion probes (440°C and 490°C) with 11 different materials exposed near the superheaters in a waste fired boiler at MVB, Hamburg.
- Superheater corrosion probe used in Idbäcken, a BFB running on waste wood. Five different materials and a temperature gradient ranging from 450°C to 600°C.
- Waterwall test panels used in Idbäcken. Four different coatings were tested.
- Corrosion probes used before and after the ESP in Idbäcken. Two temperature gradient probes and one single temperature probe with seven different materials.

Müllverwertung Borsigstrasse (MVB)

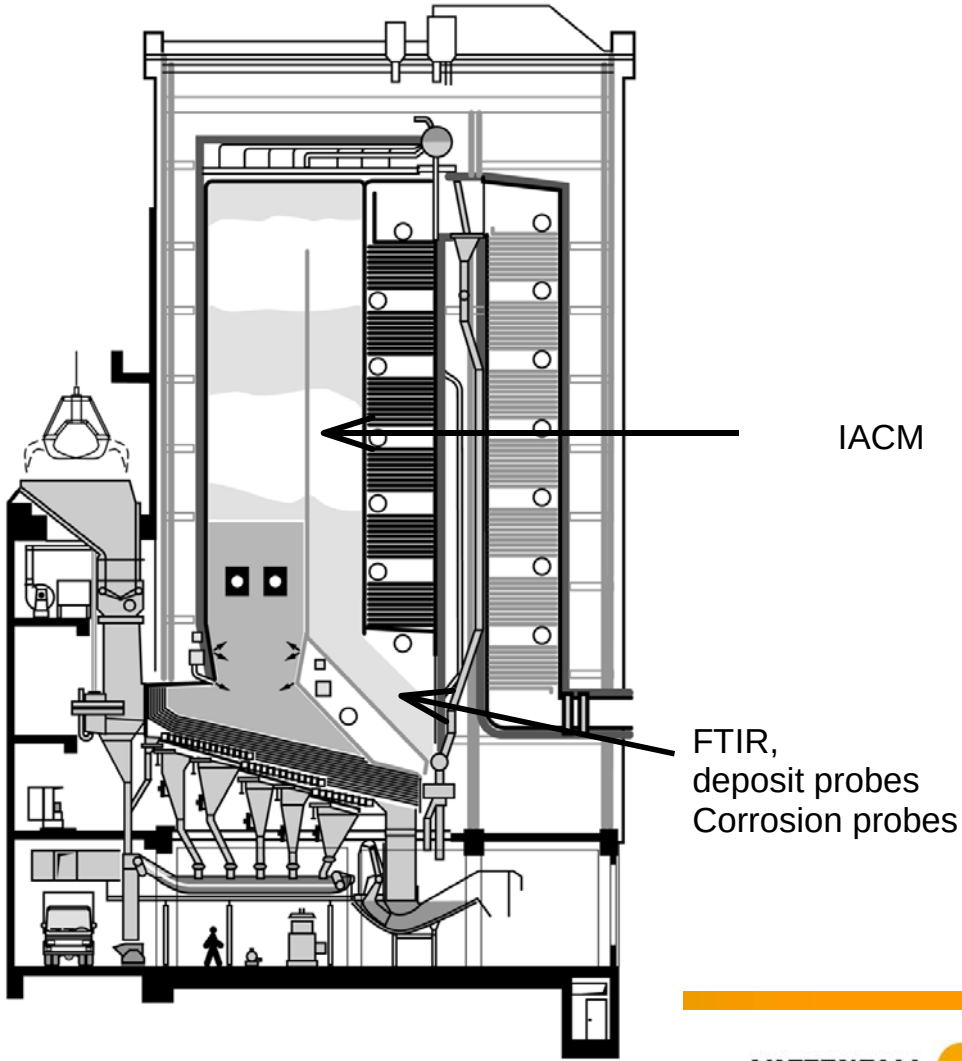
- Located in Hamburg, Germany
- Waste fired grate boiler
- 70% household waste
- 57 MW heat and steam
- Outgoing steam data: 380°C and 19 bar.

VATTENFALL

Corrosion probe testing at MVB, Hamburg

Two corrosion probes with 11 different materials exposed near the superheaters.

The metal temperatures of 440ºC and 490ºC correspond to steam temperatures of about 410ºC and 460ºC.

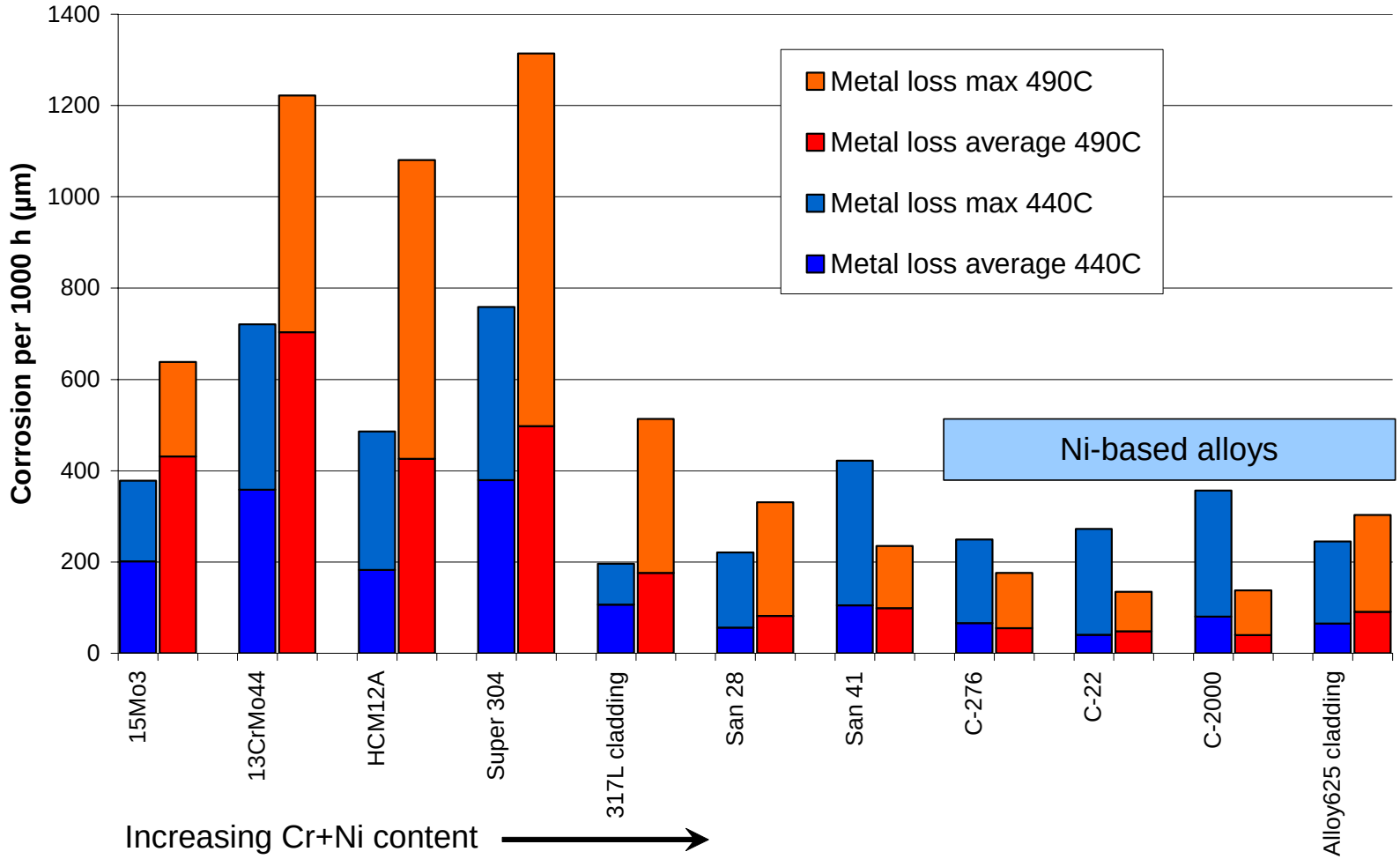


VATTENFALL

Chemical composition of the tested alloys

Alloy	Cr	Fe	Ni	Other
15Mo3	0.1	Bal.	0.09	Al 0.007, C 0.17, Cu 0.12, Mn 0.67, Mo 0.29, P 0.006, S 0.004, Si 0.22
13CrMo44	0.85	Bal.	0.10	Al 0.01, C 0.12, Cu 0.12, Mn 0.46, Si 0.23, Mo 0.5, P 0.007, S 0.003
HCM12A	11.25	Bal.	0.5	B 0.005, Mn 0.45, Si 0.5, Mo 0.45, N 0.07, Nb 0.07, V 0.25, W 2.0
Super 304	18	Bal.	9	Cu 3.0, Mn 0.8, N 0.1 , Nb 0.45
317L cladding	18.5	Bal.	14.5	C 0.03, Mn 1,7, Mo 3.1, Si 0.4
Sanicro 28	26.58	Bal.	30.64	C 0.009, Cu 0.94, Mn 1.63, Mo 3.31, N 0.046, P 0.019, S 0.0005
Sanicro 41 (alloy 825)	19.88	36.1	38.25	Al 0.06, C 0.021, Cu 1.56, Mn 0.54, Mo 2.52, S 0.0005, Si 0.27, Ti 0.66
C-276	15.54	5.24	Bal.	C 0.003, Co 1.20, Mn 0.50, Mo 15.70, P 0.007, S 0.003, V 0.2, W 3.50
C-22	21.47	3.76	Bal.	C 0.004, Co 1.36, Mn 0.24, Mo 13.09, P 0.005, S 0.003, Si 0.027, V 0.12, W 3.18
C-2000	22.54	1.22	Bal.	Al 0.24, C 0.007, Cu 1.53, Mn 0.23, Mo 15.65, P 0.004, Si 0.06
Alloy 625 cladding	21.4	1.0	64.5	Al 0.033, C 0.014, Mn 0.39, Mo 8.5, P 0.003, S 0.0021, Ti 0.21,

Material loss at two material temperatures



VATTENFALL

Conclusions MVB

Corrosion probe tests have been performed near the superheaters in a grate-fired boiler burning household waste. The temperature of the probes was controlled to 440°C and 490°C, simulating 410°C and 460°C steam and the tests lasted 1550 hours.

- The low alloyed steel 15Mo3, which is commonly used as a superheater steel in waste-fired boilers, performed well at a metal temperature 440°C in spite of its lack of protective alloying elements, but is unsuitable for use at higher temperatures.
- The alloys that performed best, especially at the higher metal temperature of 490°C, were, as expected, nickel base alloys containing chromium and molybdenum, such as alloys C-22, C-276, C-2000 and 625. These performed better at 490°C than 15Mo3 did at 440°C.
- The high strength austenitic stainless steel Super 304 performed exceedingly badly.
- Alloys C-22, C-276, C-2000 and Sanicro 41 performed better at 490°C than at 440°C.

Idbäcken CHP (boiler 3)

Located in Nyköping, Sweden

A BFB boiler producing

70 MW_{heat} 35 $MW_{electricity}$

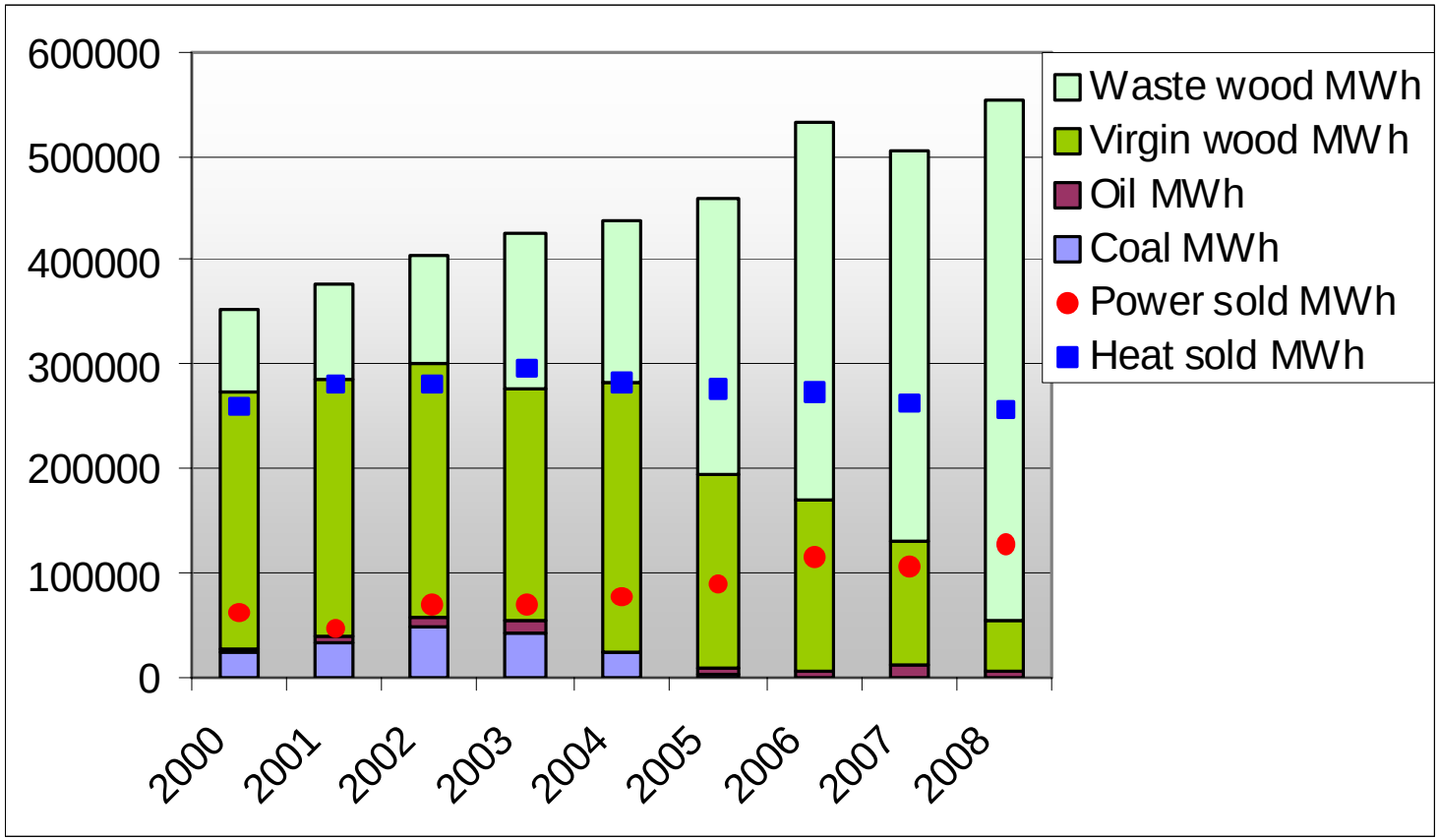
540°C/140 bar steam

Running on 100% waste wood

Permanent installation of ChlorOut (sulphate additive), used for corrosion reduction

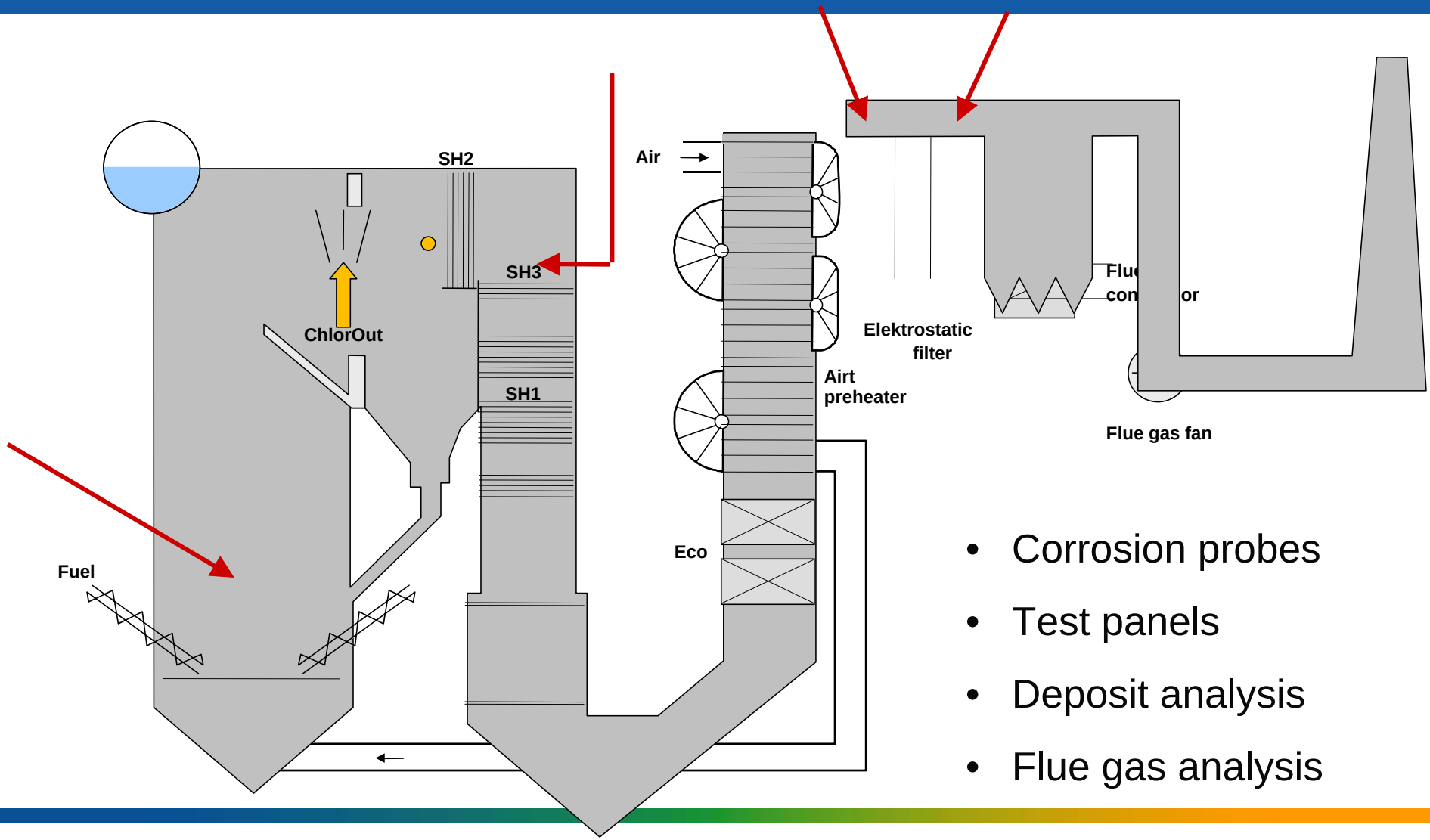
VATTENFALL

Fuel history of Idbäcken



VATTENFALL

Corrosion testing at Idbäcken CHP



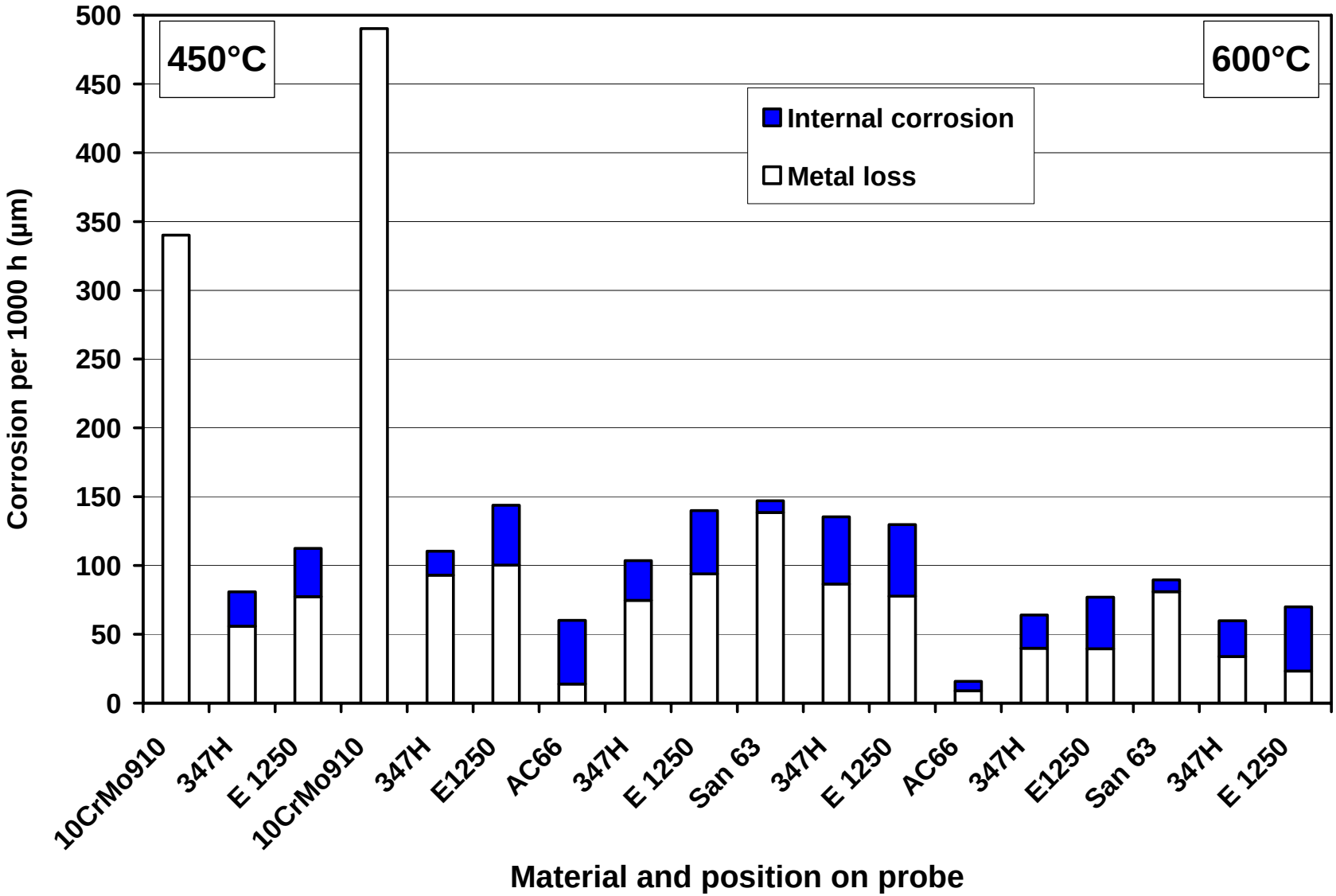
- Corrosion probes
- Test panels
- Deposit analysis
- Flue gas analysis

VATTENFALL

Materials used

Material	Cr	Fe	Ni	Övriga
10CrMo910	2.25	Bal	≤ 0.50	C 0.12, Si ≤ 0.40, Mn 0.55, Mo 1.00, Cu ≤ 0.30
Esshete 1250	15	Bal	9.5	C 0.1, Si 0.5, Mn 6.3, P≤ 0.035, S ≤ 0.015, Mo 1.0, V 0.3, Nb 1.0, B 0.005
347H	18	Bal	11	C 0.06, Si ≤0.75, Mn ≤2.0, P≤0.045, Nb ≥ 8*C; ≤ 1.0
AC66	27	Bal	32	C 0.06
Sanicro 63	21	3	Bal (63)	Mo 8.5, Nb 3.4

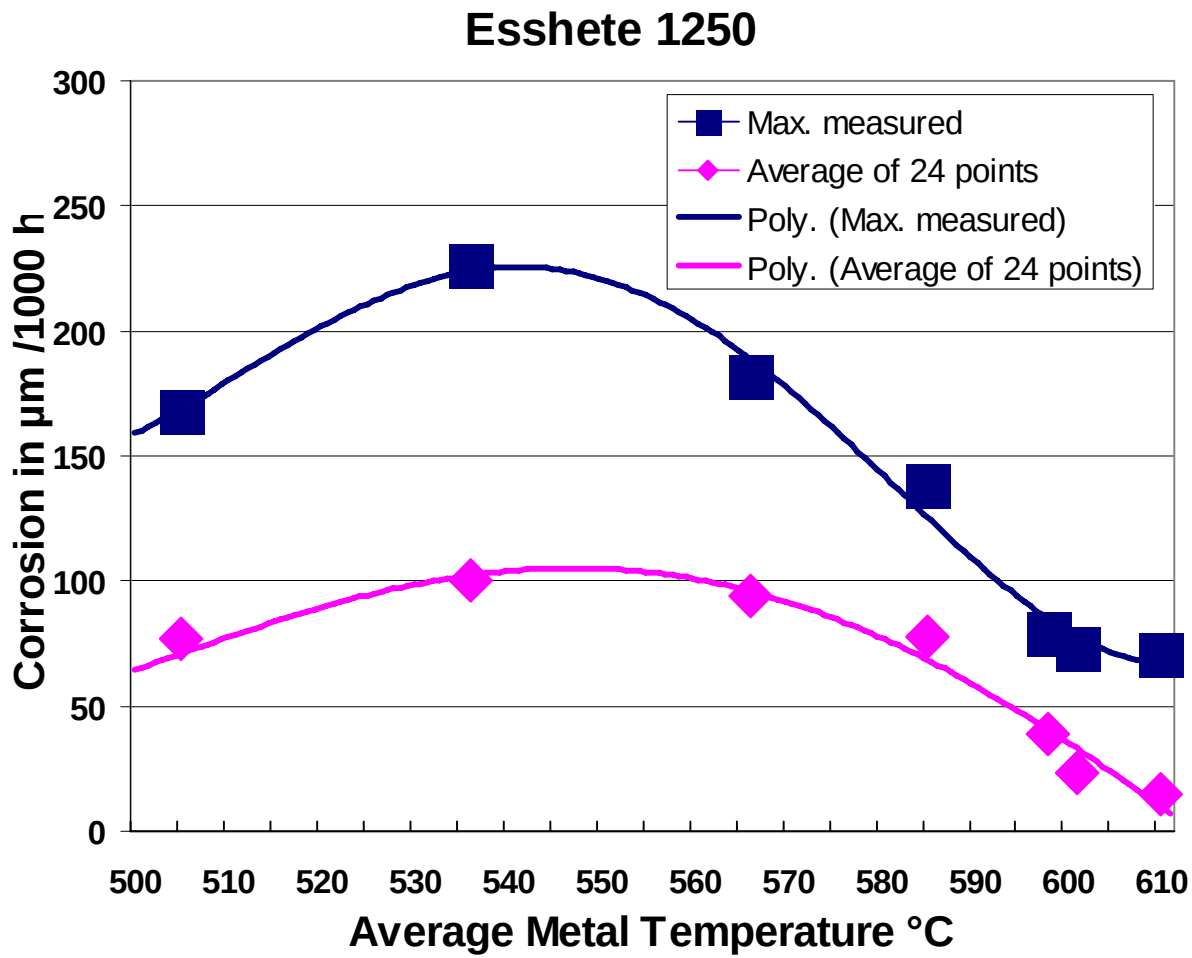
Material loss



NFALL

Material loss vs temperature, Esshete 1250

Data for 610°C from a previous test at Idbäcken is included in the diagram. 610°C corresponds to a steam temperature of 580°C, fairly close to the goal of 600°C steam.



VATTENFALL

Conclusions

Corrosion probe testing, simulating superheater corrosion was performed in a boiler firing 100% waste wood and using ChlorOut (ammonium sulphate).

- Corrosion rate for 10CrMo910 was very high
  – 490µm/1000 hours => ca 3,9mm/7000h
- The austenitic steels TP 347H, Esshete 1250 and AC66 as well as the nickel base material Sanicro 63 had relatively low corrosion rates. AC66 is the material showing the best results.
- The austenitic steels and the nickel-base alloy showed lower corrosion rates in the region of 600°C metal temperature, than at 580°C or below, indicating that it is possible to reach high steam temperatures when burning 100% waste wood.

Superheater corrosion and temperature

- It has been shown that increasing the material temperature can actually result in lower corrosion when using corrosion resistant materials.

- There is a logical explanation for this. The chloride level in the deposits decreases as the temperature increases and it is believed that the stainless steels can more easily form a protective chromium oxide layer at higher temperatures.

- The results indicate that it is possible to reach high steam temperatures when burning 100% waste wood and other bio fuels. A combination of ChlorOut and corrosion resistant steels is believed to be useful in achieving this.

Thank you!

VATTENFALL