

Increased steam temperature with Steamboost superheater in grate fired boilers – *linking deposit formation and high temperature corrosion (KME709)*



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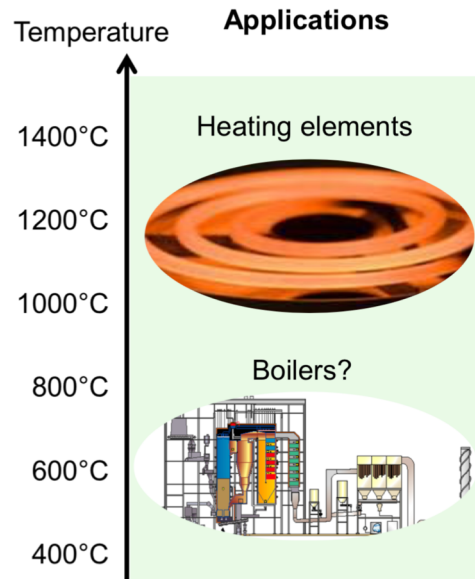
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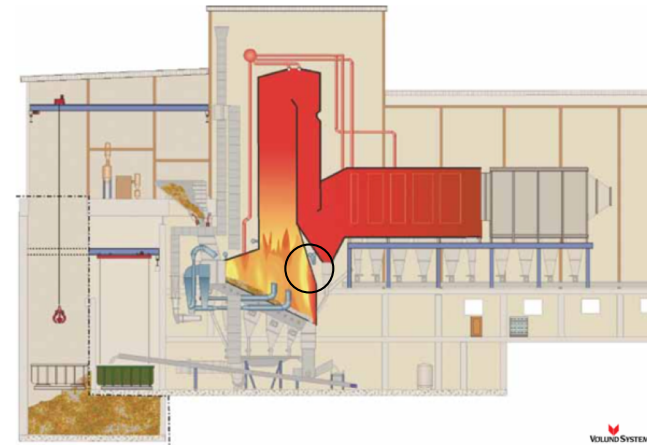


Research strategy and correlation to KME goals



Alumina forming alloys - FeCrAl

Combined heat and power plant
AffaldPlus, Denmark



Waste fired boilers - New position of superheaters

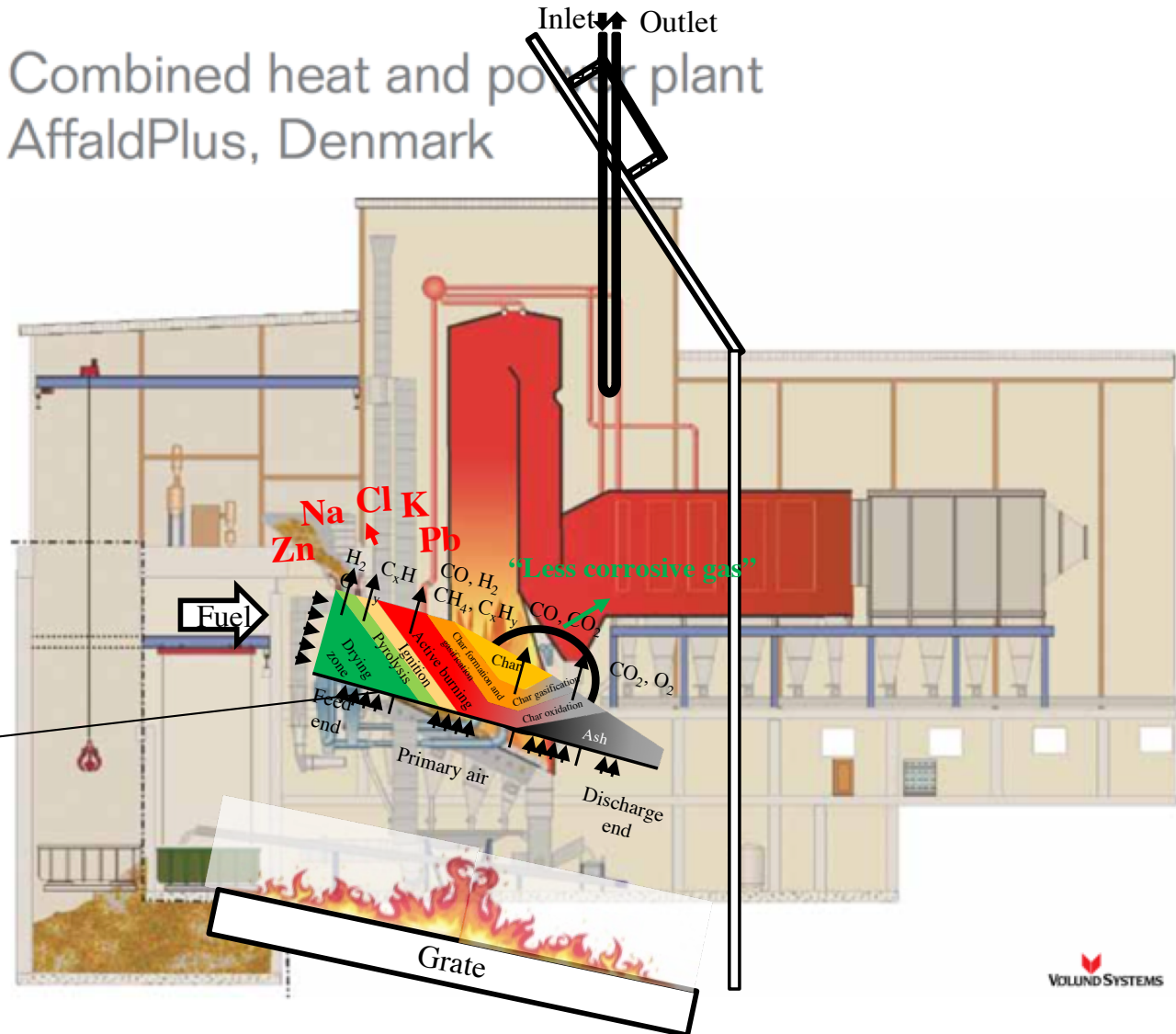
- Higher steam parameters & high electrical efficiency
- Development of novel solutions where steam is superheated in the furnace
- Develop improved material solutions – including alumina formers

Grate fired boiler

- What's the idea behind Steamboost?

Combined heat and power plant
AffaldPlus, Denmark

- Waste fired boiler.
- Different processes over the grid.
- **CFD calculations indicates a position over the grid with less corrosive species.**
- **New position of superheaters!**



Research strategy - Steamboost

Investigate the Steamboost position in a commercial plant – AffaldPlus

CFD modeling

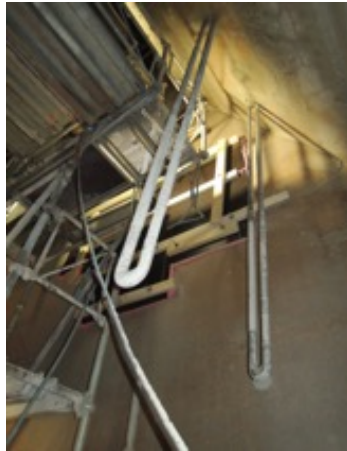
Fixed installations

Deposit tests

Corrosion tests



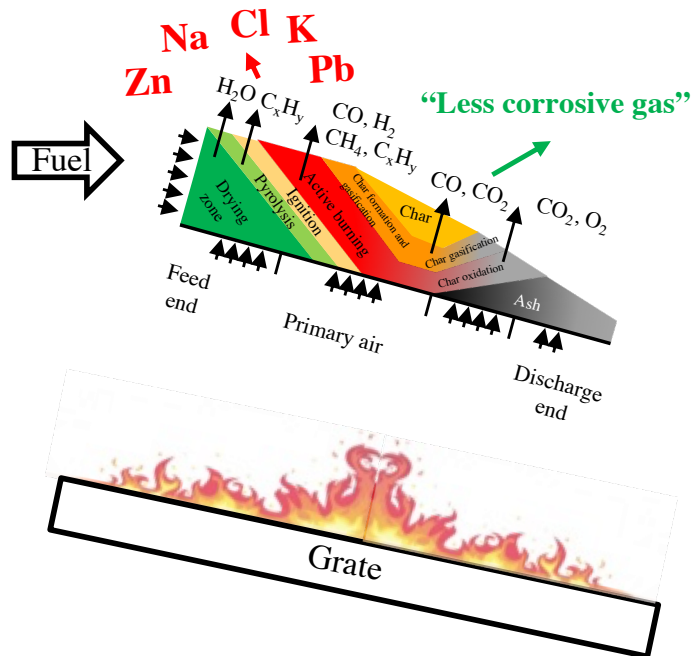
Deposit test



Inlet Outlet

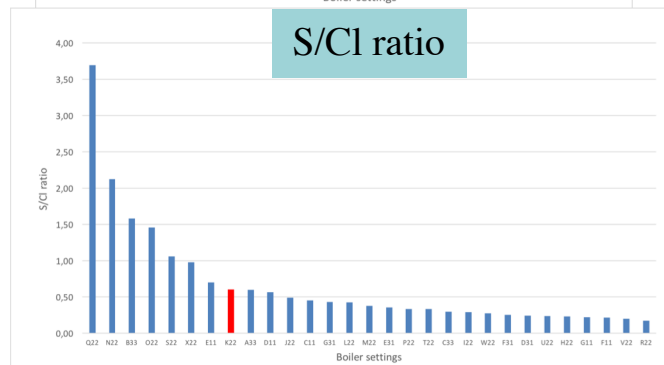
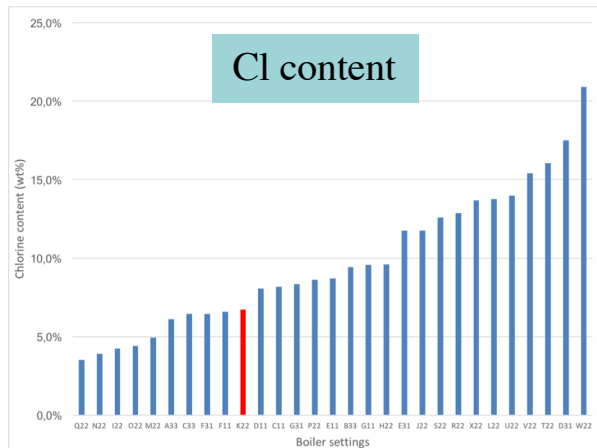
Probe exposures

Deposit test



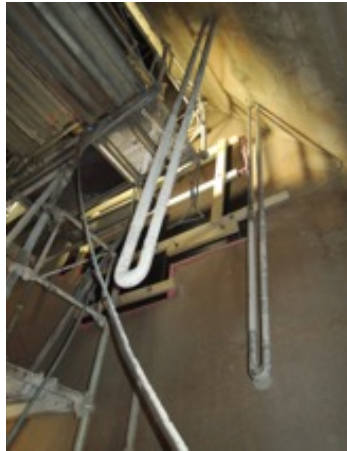
- Deposit test – 2 hours exposures
- High alloyed Stainless steel samples
- Temperatures 525 and 700°C
- 29 exposures

Deposit investigation – impact of boiler settings



- Large number of settings tested – deposits formed at 525° C and 700° C
- Small/no difference between exposure temperatures
- All aspects of deposit formation possible to influence

Corrosion test - probe



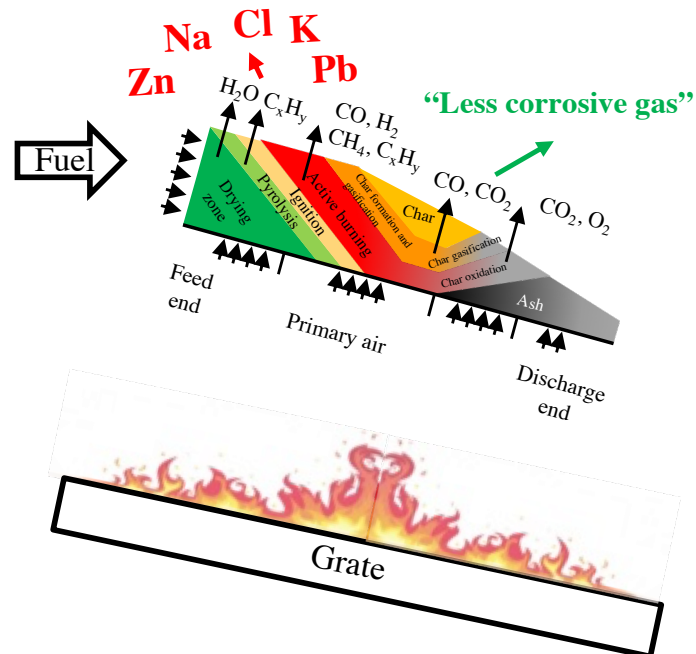
Inlet Outlet

Probe exposures

Corrosion test

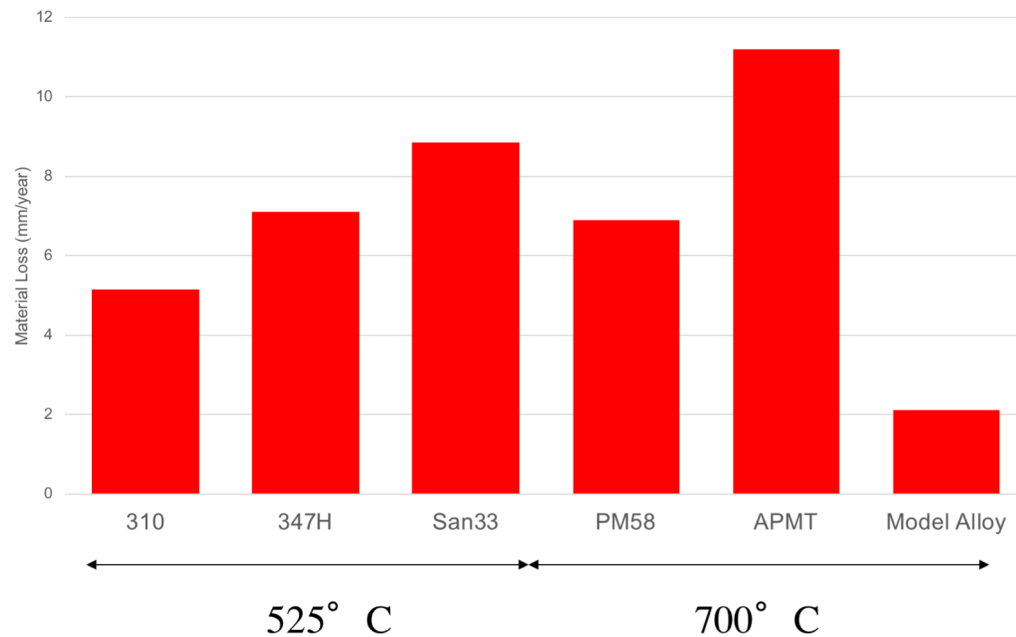


700° C 525° C



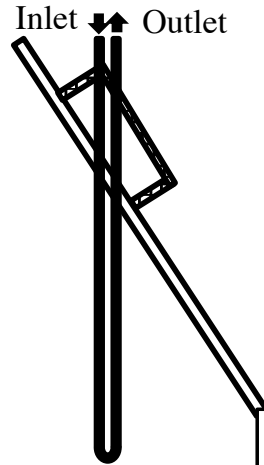
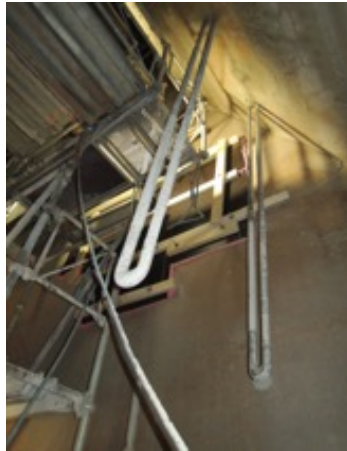
- Corrosion test – 24 and 1000 hours exposures
- Stainless steels, High alloyed Stainless steel and FeCrAl samples
- Temperatures 525 and 700 °C

Corrosion investigation – probe exposures

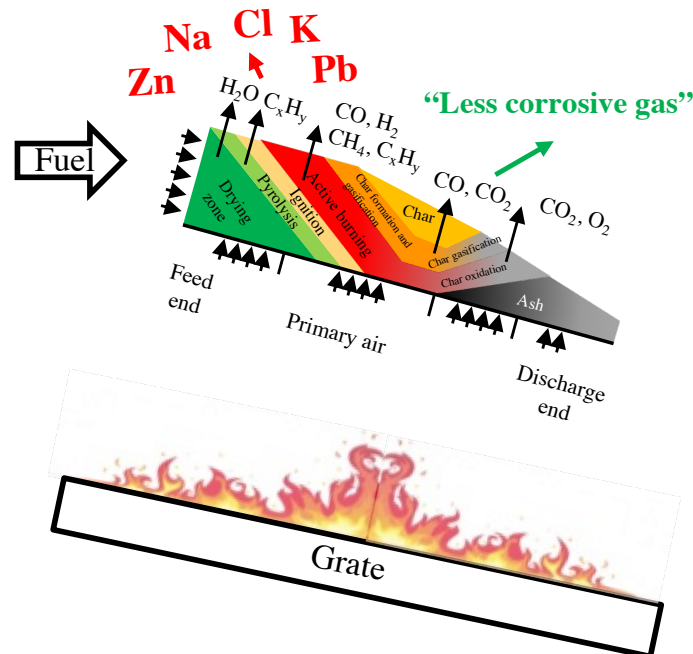


- Generally high corrosion rates, both at 525° C and 700° C
- Higher levels of Cl detected in corrosion products after short exposures (24h)
- No clear trends: alloying element – corrosion resistance
- FeCrAl Model alloy (indications of protective alumina)

Corrosion test – fixed installed material

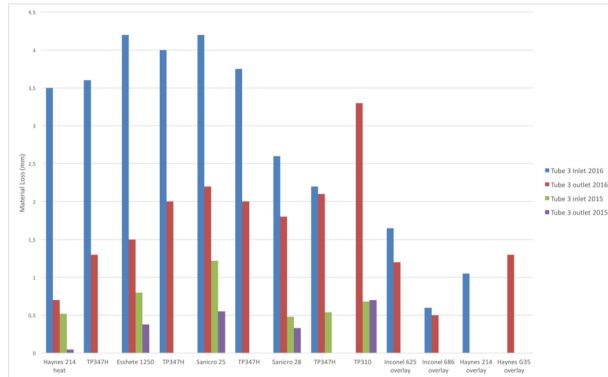


Corrosion test

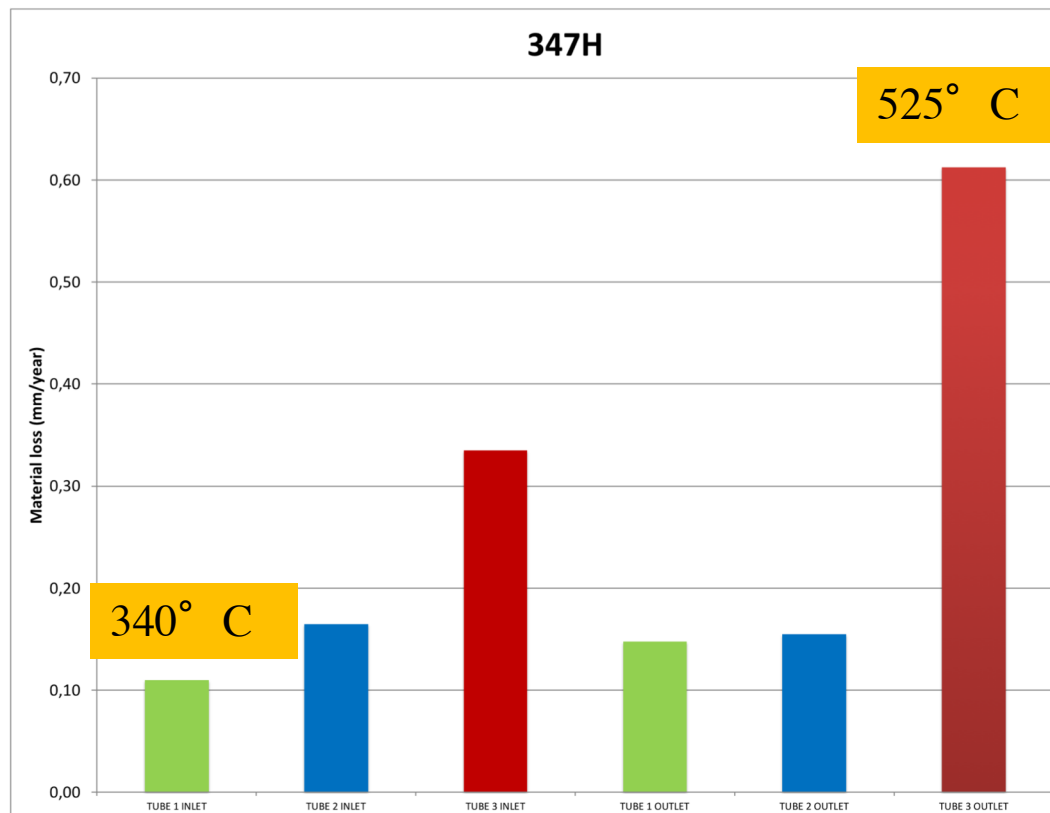


- Corrosion test – 8000h and about 6000 hours exposures
- Stainless steels, High alloyed Stainless steel and FeCrAl samples
- Temperatures 340-525 °C

Material loss - Steamboost



- Many materials investigated
- Tested during the deposit-setting tests

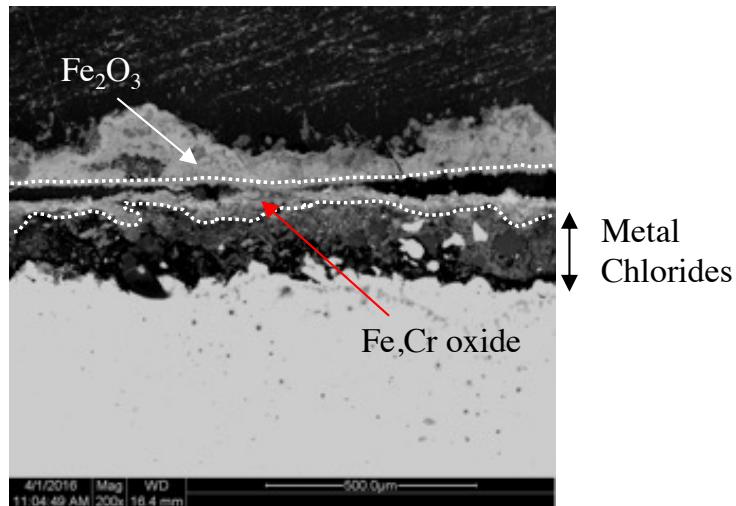


- Low corrosion rates observed at the tubes with temperatures 340-470C
- Higher corrosion rates at 525C – very high for some samples
- Promising corrosion rate for some samples – 347H (one of the exposures)

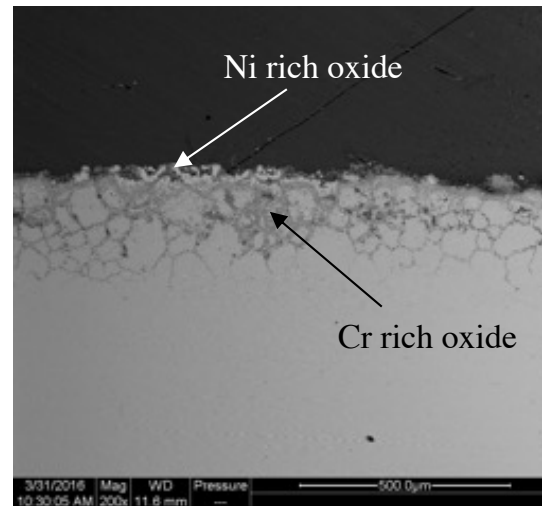
Corrosion attack - microstructure

347 stainless steel

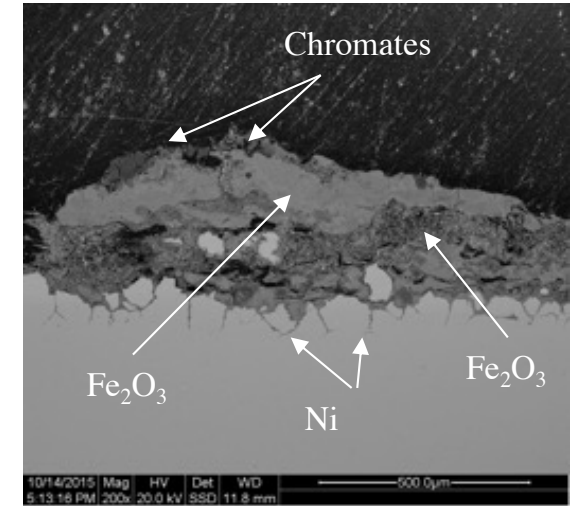
24h 525C



1000h 525C



8000h Steamboost

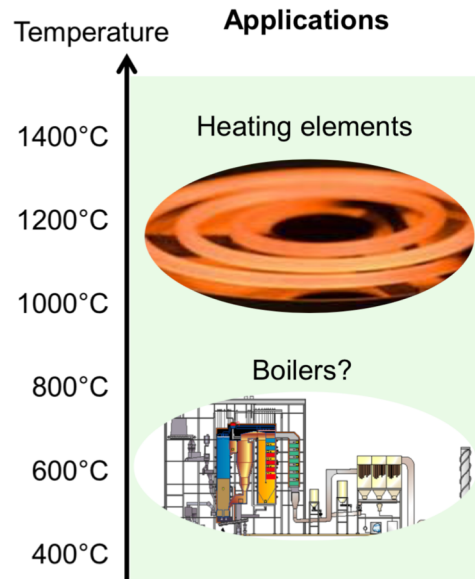


Air cooled probe

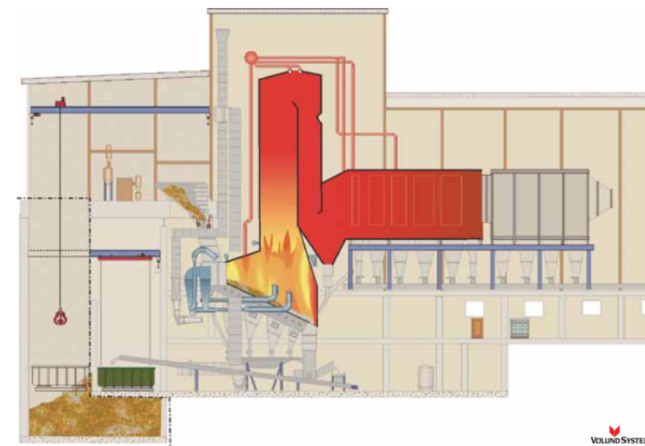
Steamboost - summary of the results

- It is possible to influence all aspects of deposit formation at the Steamboost position by changing the settings of the boiler
- Probe tests showed high corrosion rates compared to fixed installed samples. However, similar type of corrosion attack as the fixed installation. Higher Cl content on the probe samples (short exposures)
- The FeCrAl model alloy sample show promising corrosion behavior in this environment
- Fixed installed samples – exposed during deposit tests. Promising results on some material/samples – high corrosion rates on some samples. More work needed

Research strategy and correlation to KME goals



Combined heat and power plant
AffaldPlus, Denmark

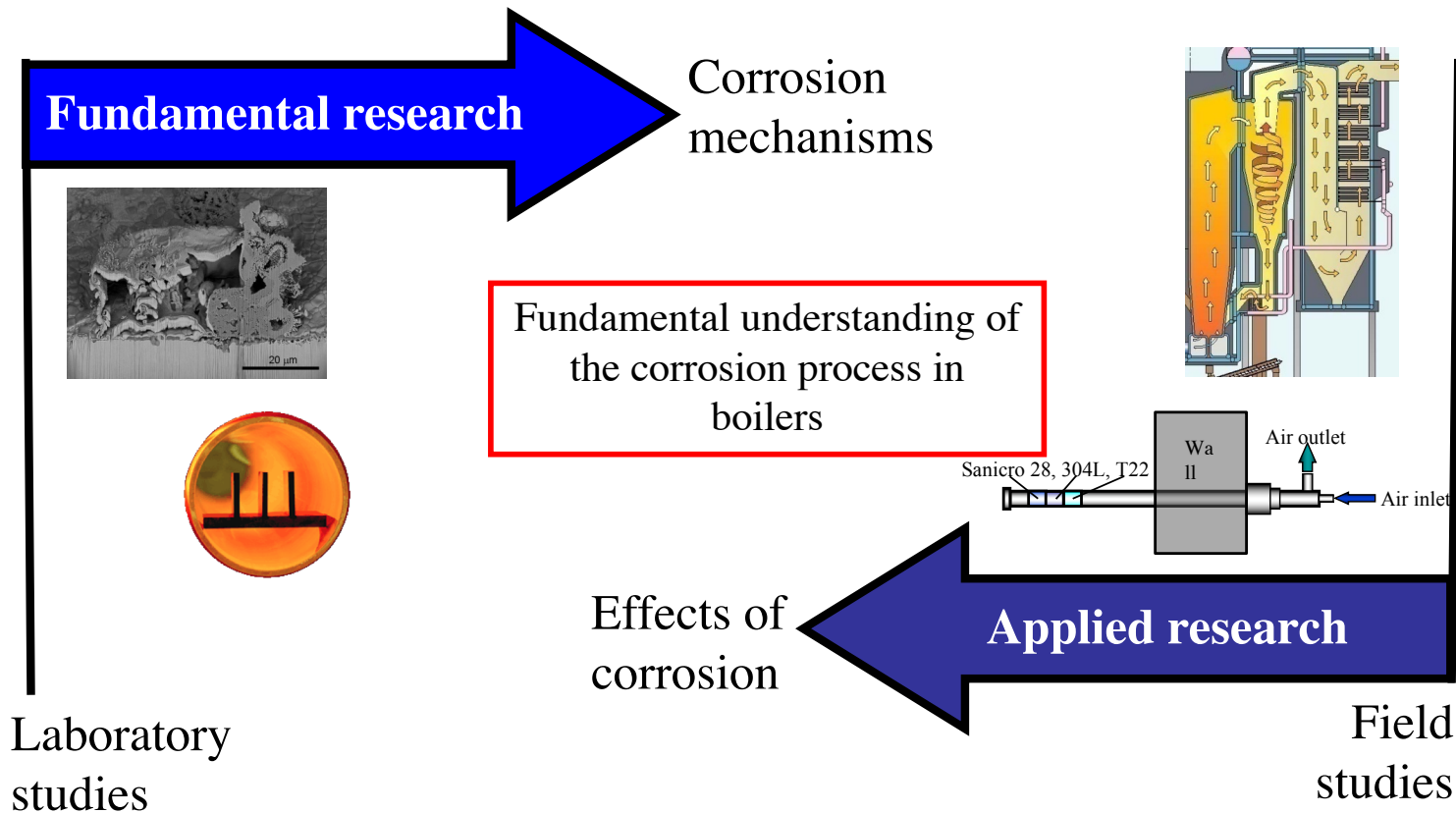


Alumina forming alloys - FeCrAl

Waste fired boilers - New position of superheaters

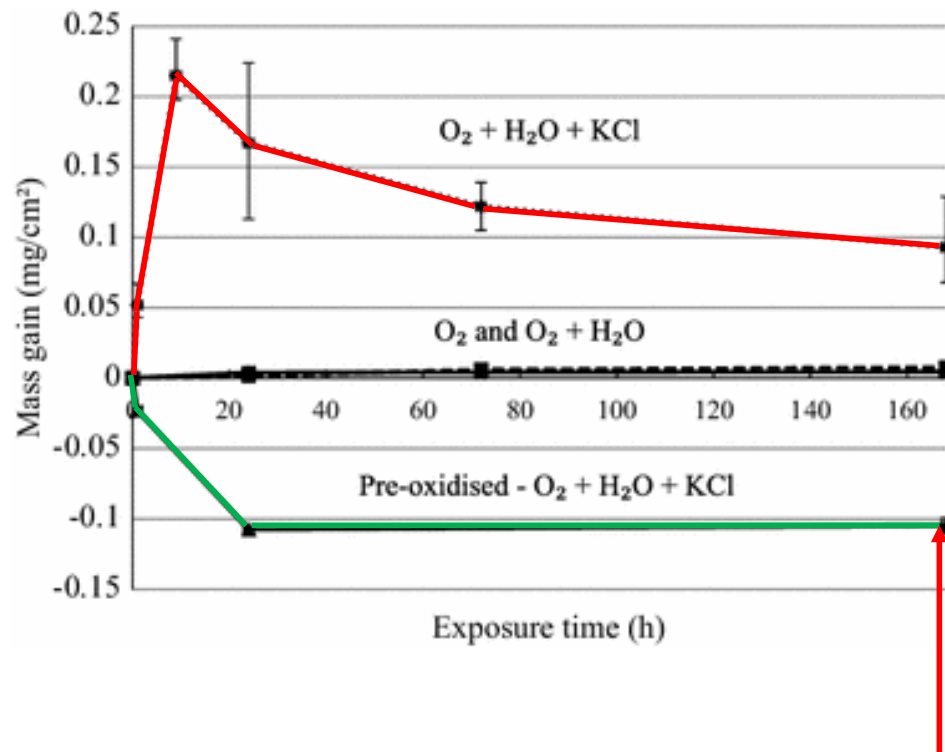
- Higher steam parameters & high electrical efficiency
- Development of novel solutions where steam is superheated in the furnace
- Develop improved material solutions – including alumina formers

Research strategy – a two pronged approach



- Preoxidation of FeCrAl alloys
- Optimizing FeCrAl alloy composition

Pre-oxidation of FeCrAl alloys



- Pre-oxidized FeCrAl samples tested in the lab (HTC)
- Al₂O₃ formed at higher temperatures – resists accelerated corrosion by KCl

Protective alumina – KCl evaporation - no corrosion

Boiler exposure – un-cooled FeCrAl tube

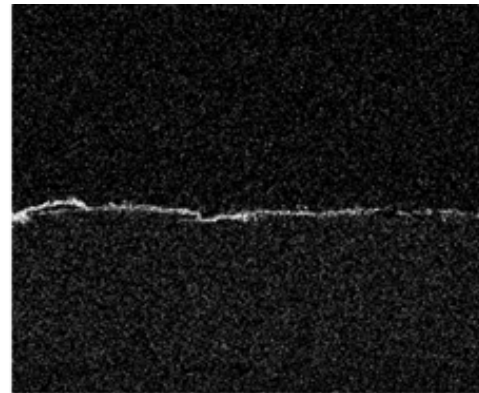
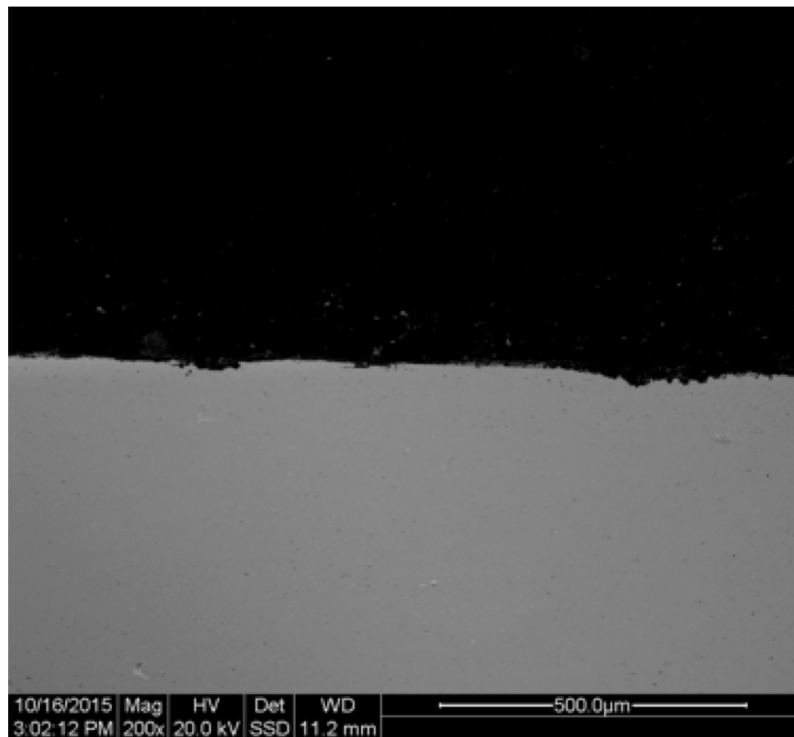


Pre-oxidized FeCrAl tube exposed at the steamboost position at 900 C

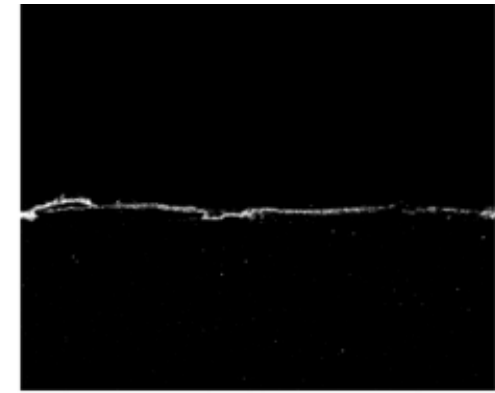
- Pre-oxidized FeCrAl samples tested in the lab (HTC)
- Al_2O_3 formed at higher temperatures – resists accelerated corrosion by KCl

Boiler exposure – un-cooled FeCrAl tube

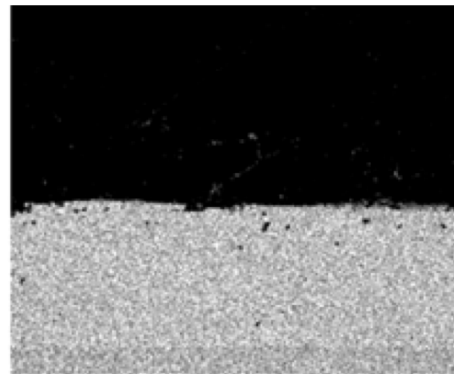
Protective alumina!



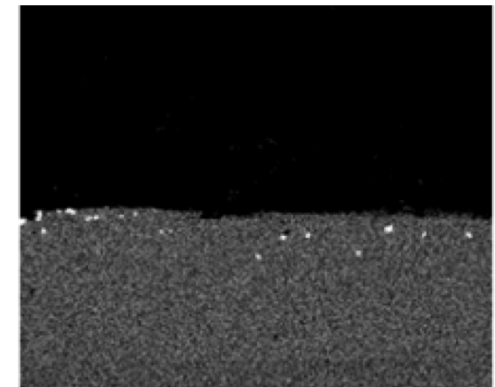
O Ka1



Al Ka1



Fe Ka1

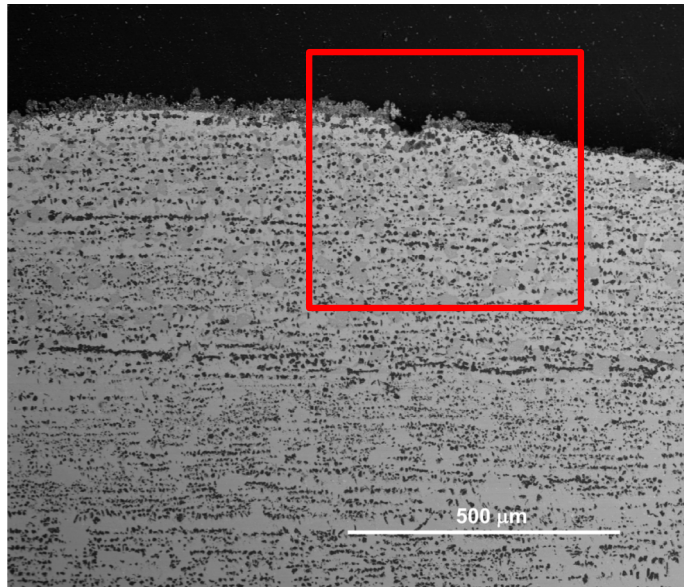


Cr Ka1

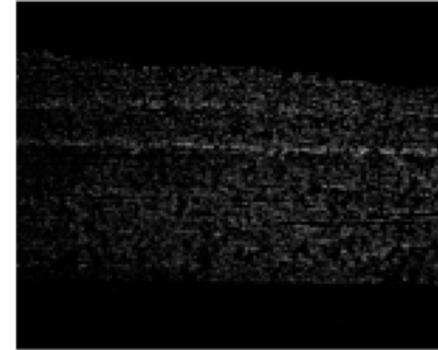
Temperature $\approx 900^{\circ}\text{C}$ Time ≈ 4500 h

Boiler exposure – un-cooled FeCrAl tube

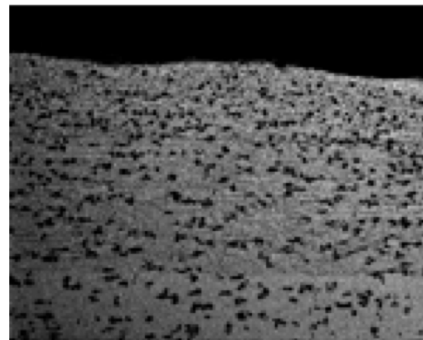
Lost protective alumina – fast corrosion - failure



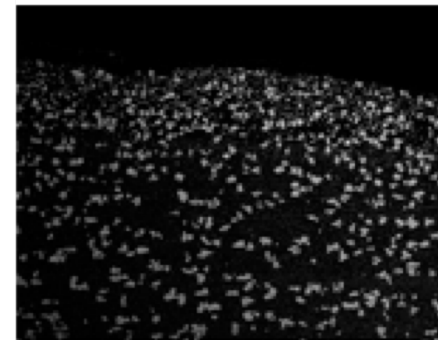
O Ka1



Al Ka1



Fe Ka1

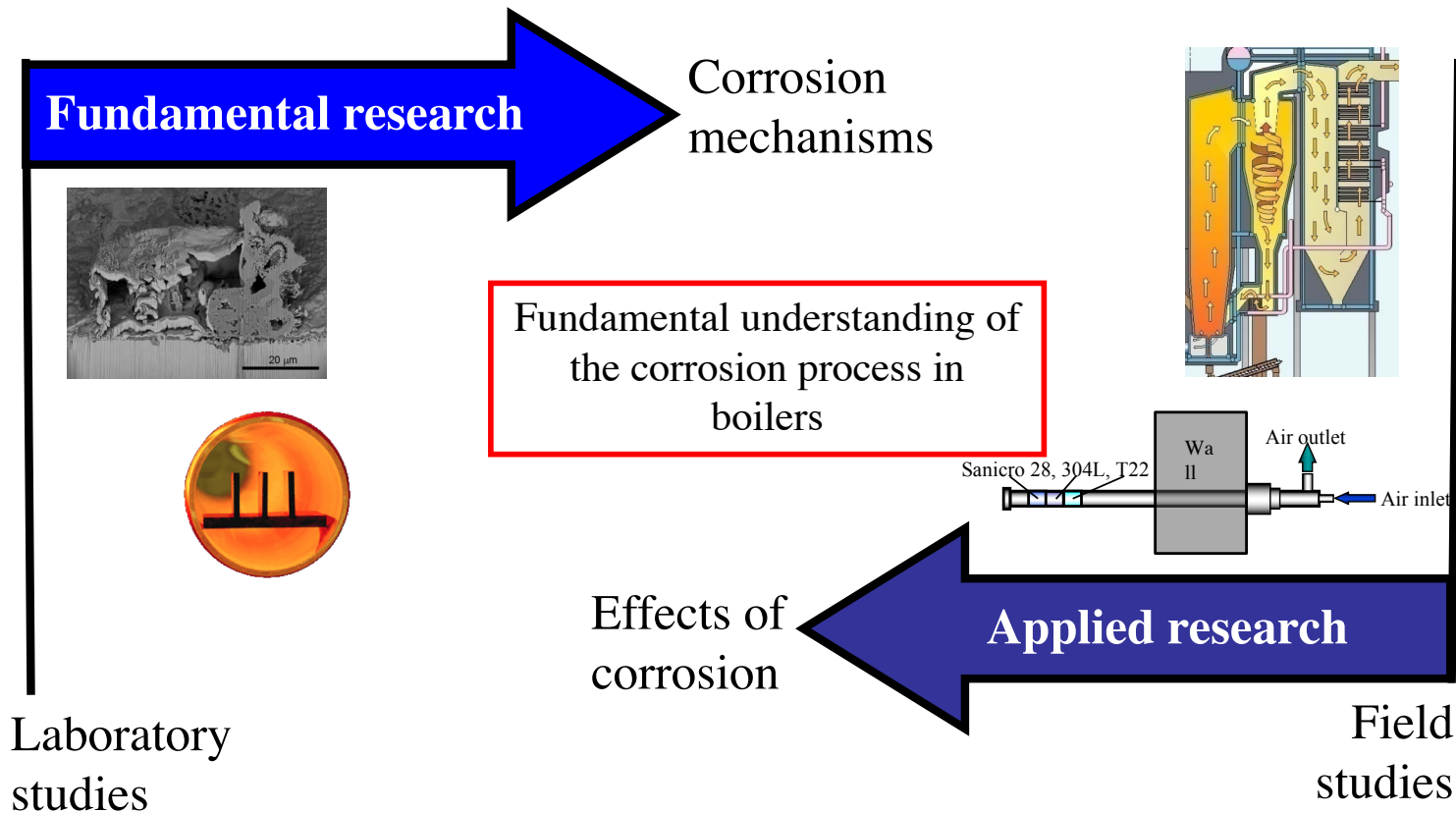


Cr Ka1



Temperature $\approx 900^{\circ}\text{C}$ Time ≈ 12000 h

Research strategy – a two pronged approach



- Preoxidation of FeCrAl alloys
- Optimizing FeCrAl alloy composition

FeCrAl alloys are potential materials for biomass and waste fired environments



Develop new FeCrAl alloys for biomass and waste fired environments

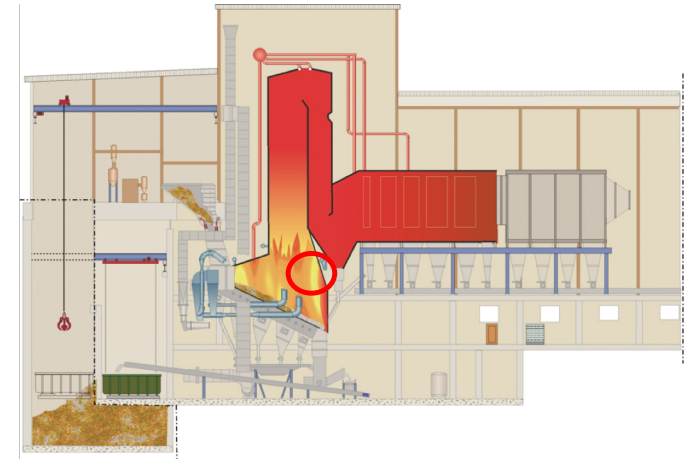


Can the same trends be observed in the real applications

Existing FeCrAl alloys are optimized for higher temperatures



In close collaboration with Kanthal



Two trends observed:

- Decreased amount of corrosion upon addition of Cr and Si

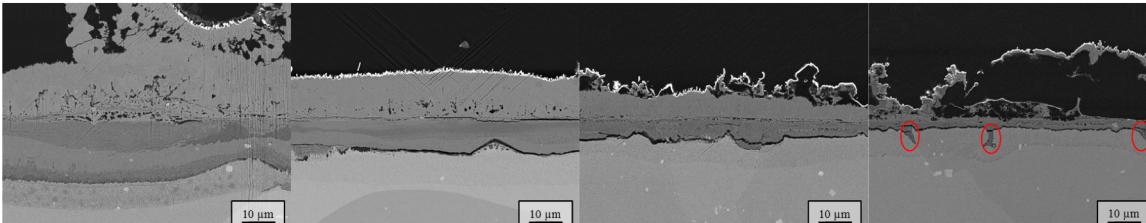
Cr

5%

10%

15%

20%

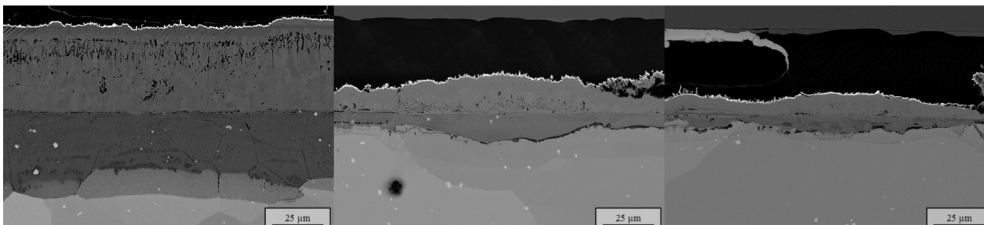


Si

0%

1%

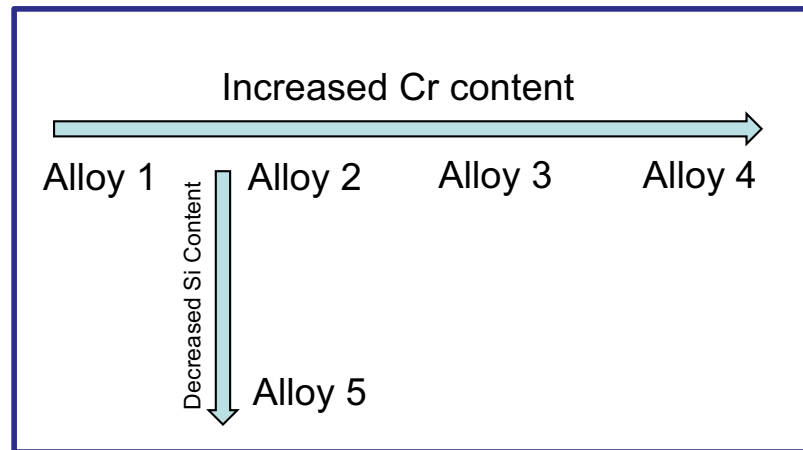
2%



Collaboration with HTC (1a)

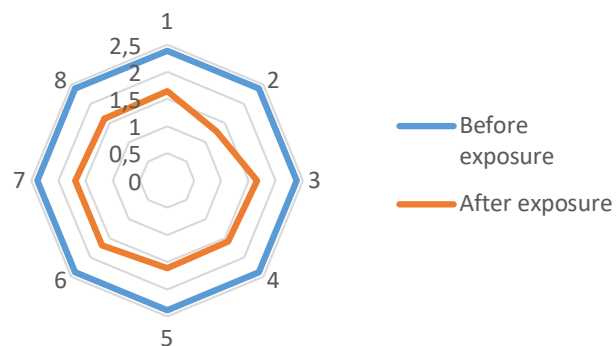
Alloys for field exposures (600° C) Part of KME 709

Probe with 8 sample locations:

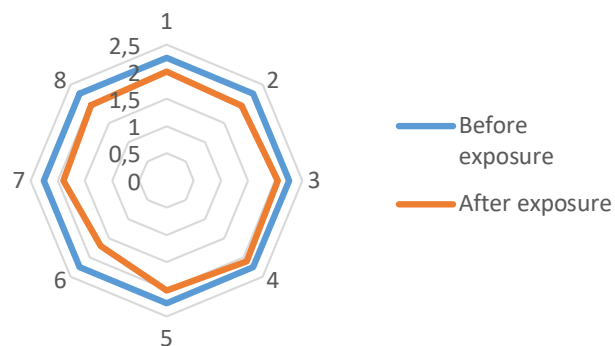


ref	1	2	3	4	5
Alloy 625	5 3 2	10 3 2	15 3 2	20 3 2	10 3 0
	Cr Al Si				

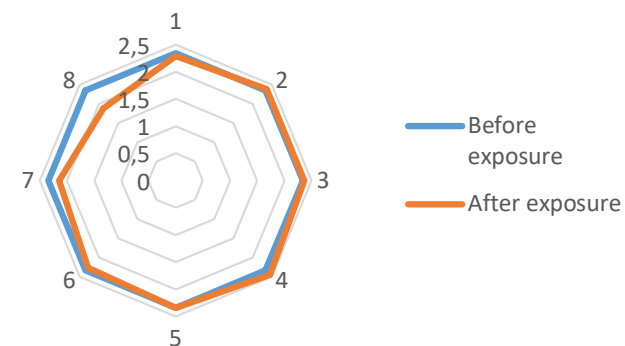
Alloy 1 (5Cr-3Al-2Si)



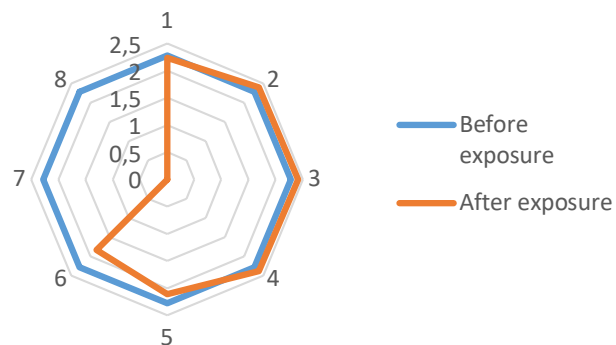
Alloy 2 (10Cr-3Al-2Si)



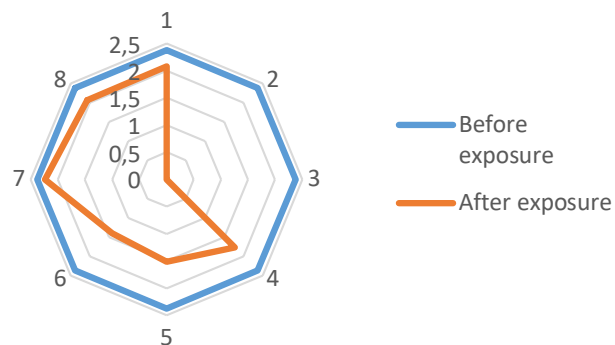
Alloy 3 (15Cr-3Al-2Si)



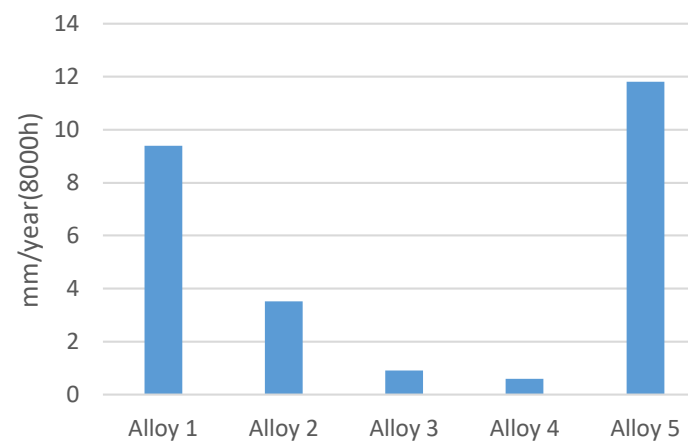
Alloy 4 (20Cr-3Al-2Si)

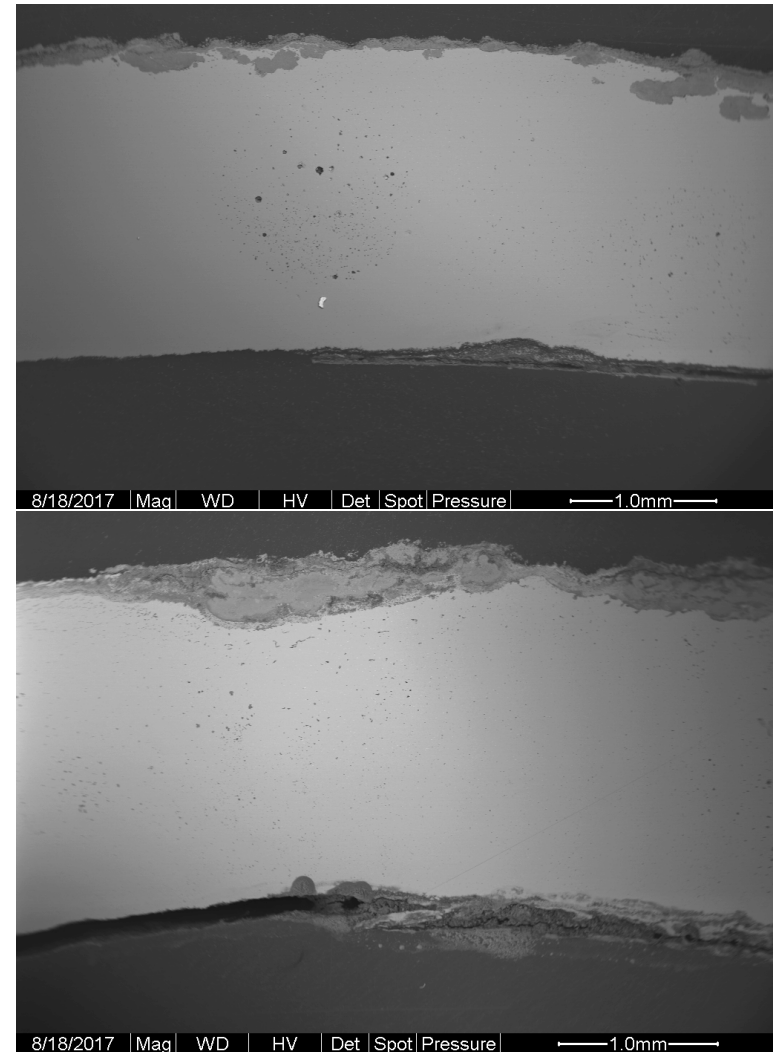
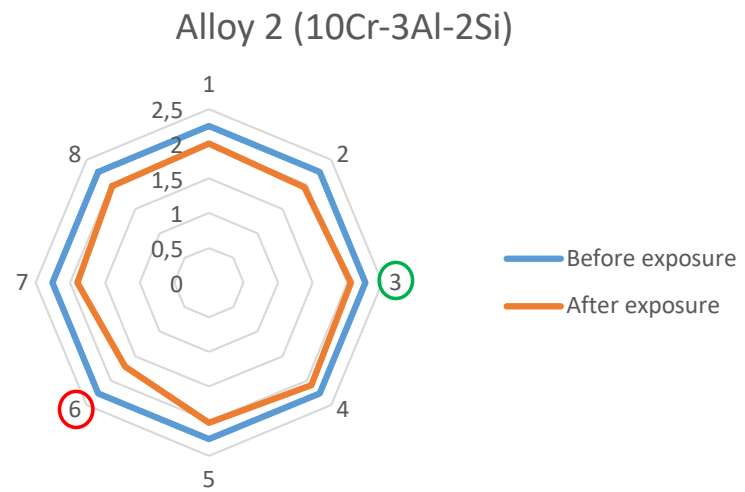


Alloy 5 (10Cr-3Al-0Si)



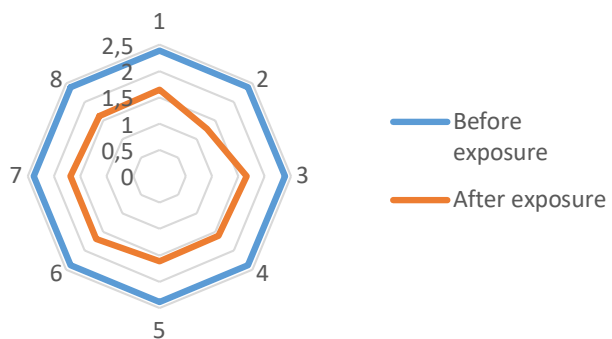
Material loss



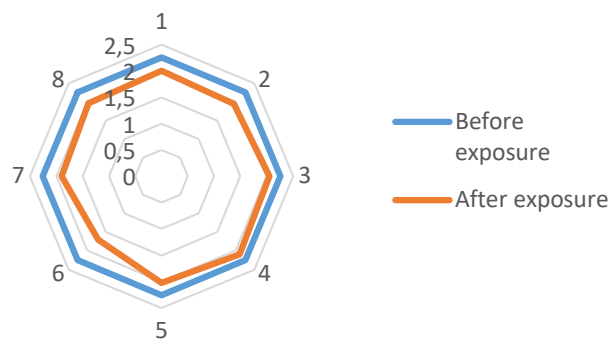




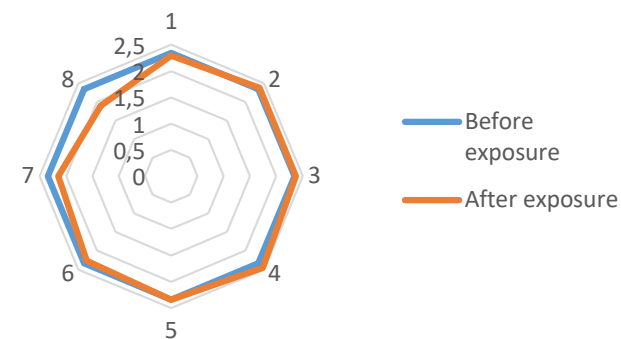
Alloy 1 (5Cr-3Al-2Si)



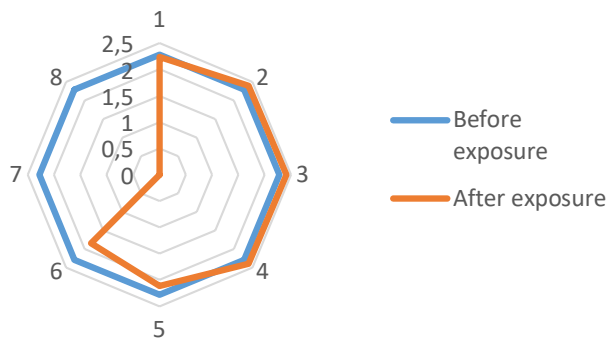
Alloy 2 (10Cr-3Al-2Si)



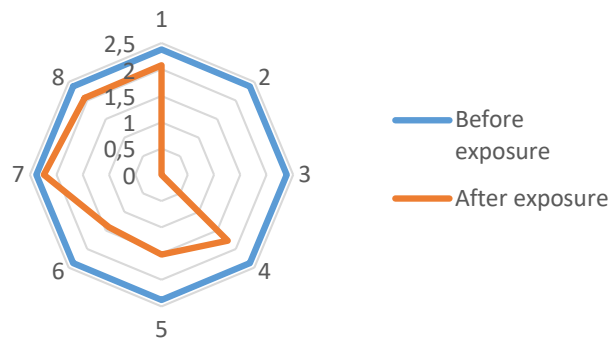
Alloy 3 (15Cr-3Al-2Si)



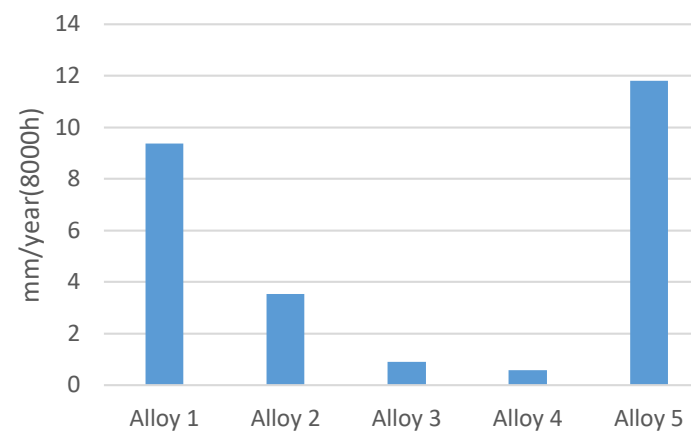
Alloy 4 (20Cr-3Al-2Si)

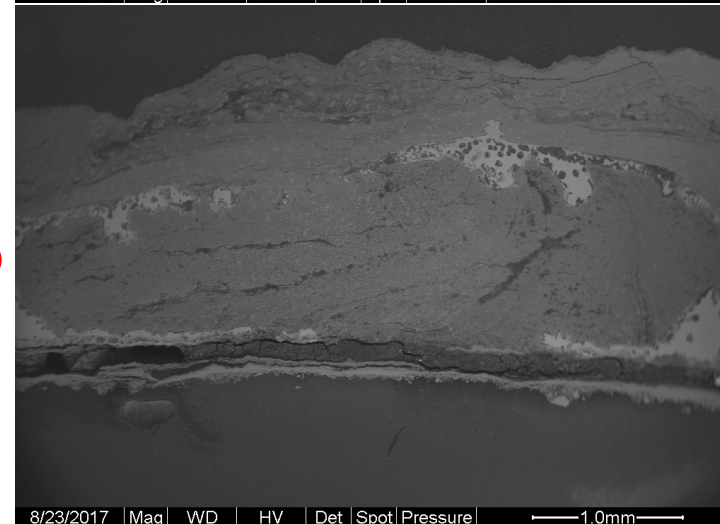
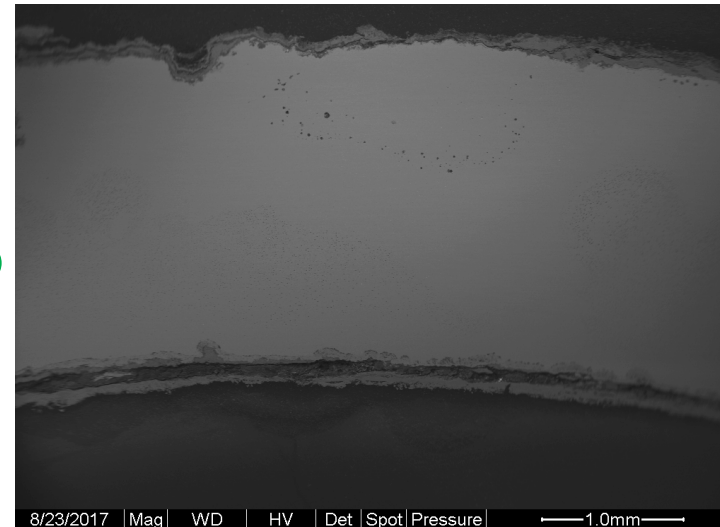
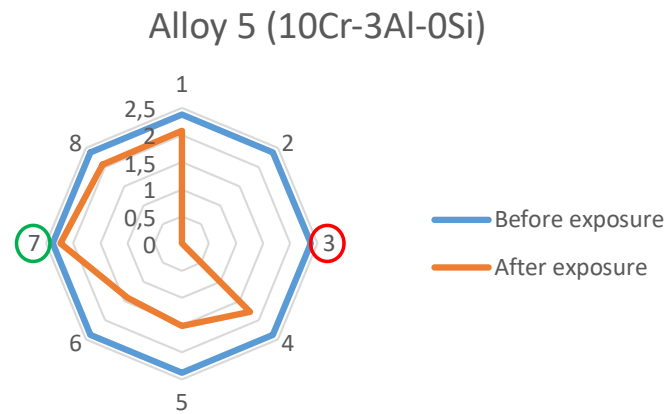


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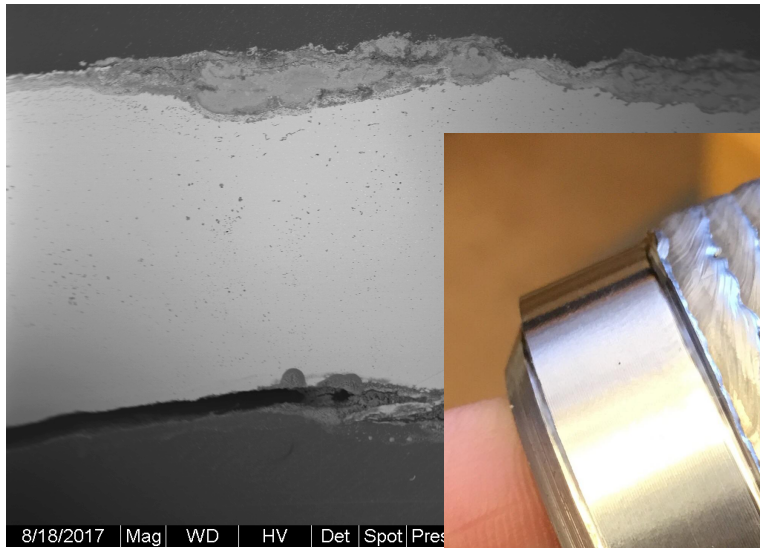


Material loss

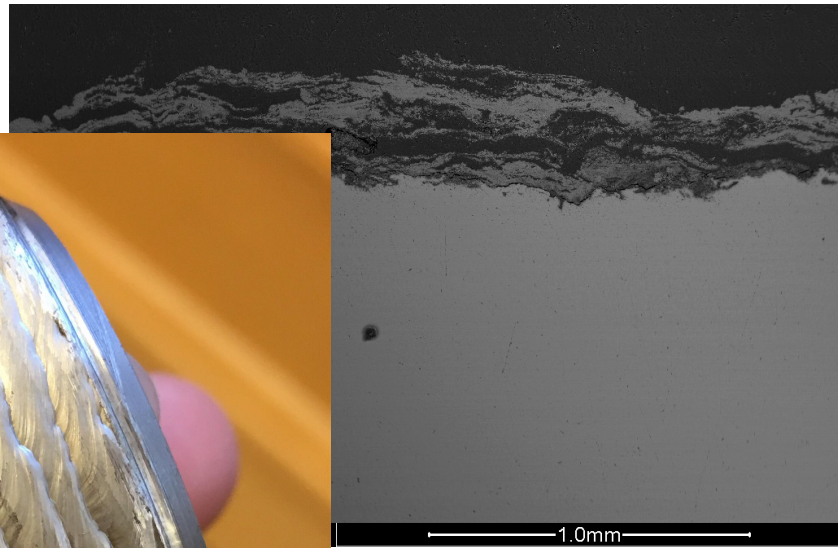




Comparison with state of the art materials in these environments



Alloy 2 (10Cr-3)



Inconel 625

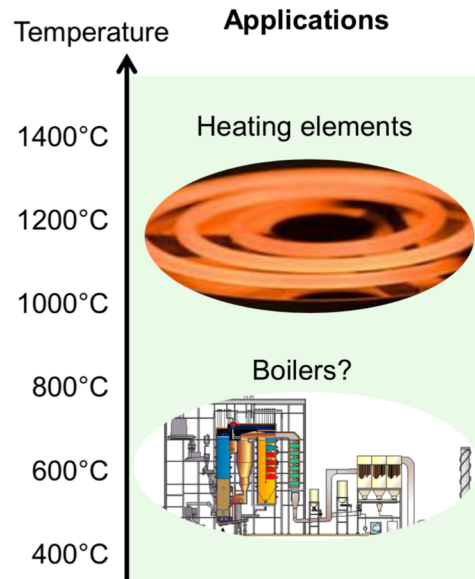


Inconel 625

Summary - FeCrAl

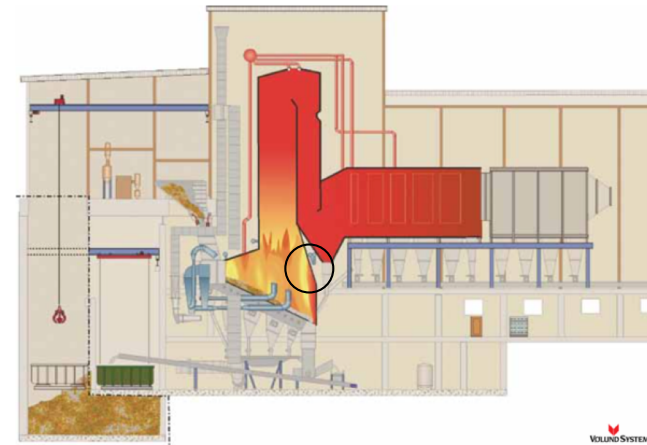
- Similar trends observed for field and lab exposures
- Pre-oxidizing FeCrAl alloys prior to exposure results in a protective alumina layer
 - Decreased corrosion attack
 - Alumina fails during cycling and results in severe corrosion attack
- Addition of Cr results in a better corrosion resistance but makes the material more brittle
- Large difference in corrosion attack upon addition of Si
 - Decrease in material loss
- Some of the FeCrAl alloys show comparable corrosion resistance as state of the art materials in this environment

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