Sulfur recirculation and improved material selection for high temperature corrosion abatement – Investigating different aspects of corrosion memory

(KME 714)

B&W vølund
f.d. Götaverken Miljö
Sven Andersson
Thomas Norman
Lars Mikkelsen

MAABJERG ENERGY CENTER
HOLSTEBRO STRUER
Ove Hauris Jespersen
Niels Peder Hansen

AVANCEZ 1829
Torbjörn Jonsson
Jesper Liske
<u>Loli Paz</u>
Julien Phother

DONG energy
Søren Aakjær Jensen

DTU
Kristian Vinter Dahl
Melanie Montgomery
Yohanes Malede

Overall Goal of KME714

- Research strategy and correlation to KME goals

Sulfur recirculation + Corrosion memory

- Sulfur recirculation → Laboratory studies, Full scale installation
- Corrosion memory → Environment, Material

KME goals:

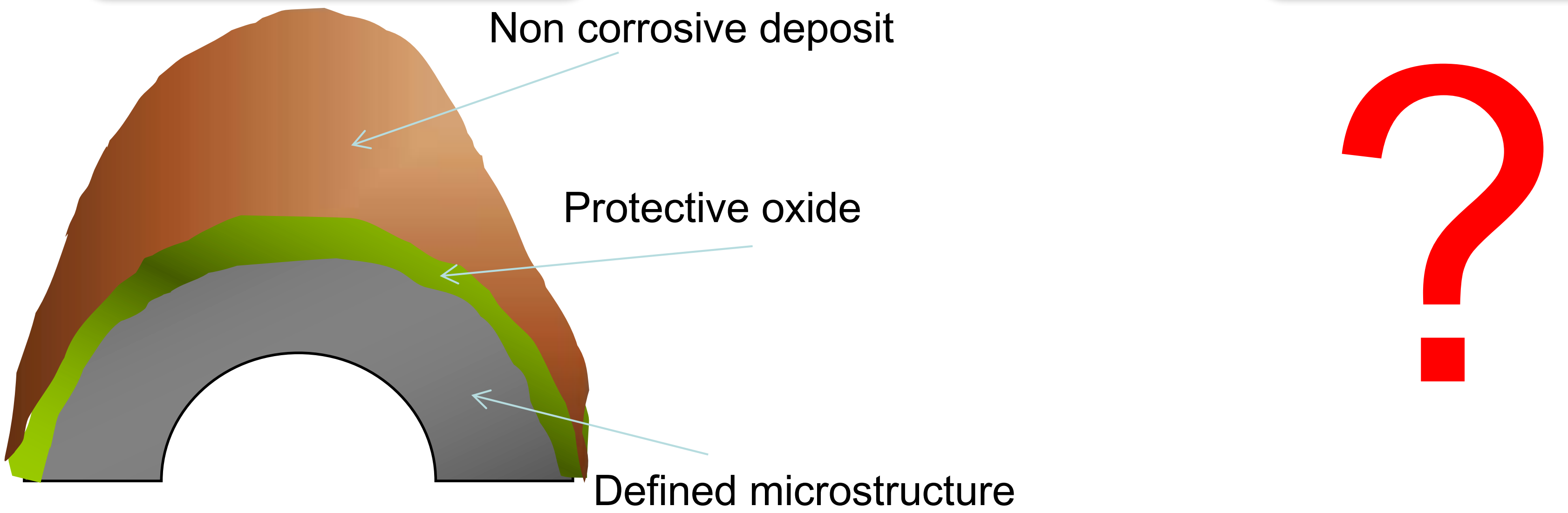
- Increase green electricity production from combustion of biomass and waste
- Improved fuel flexibility
- Improved material design/selection

Corrosion memory – definition

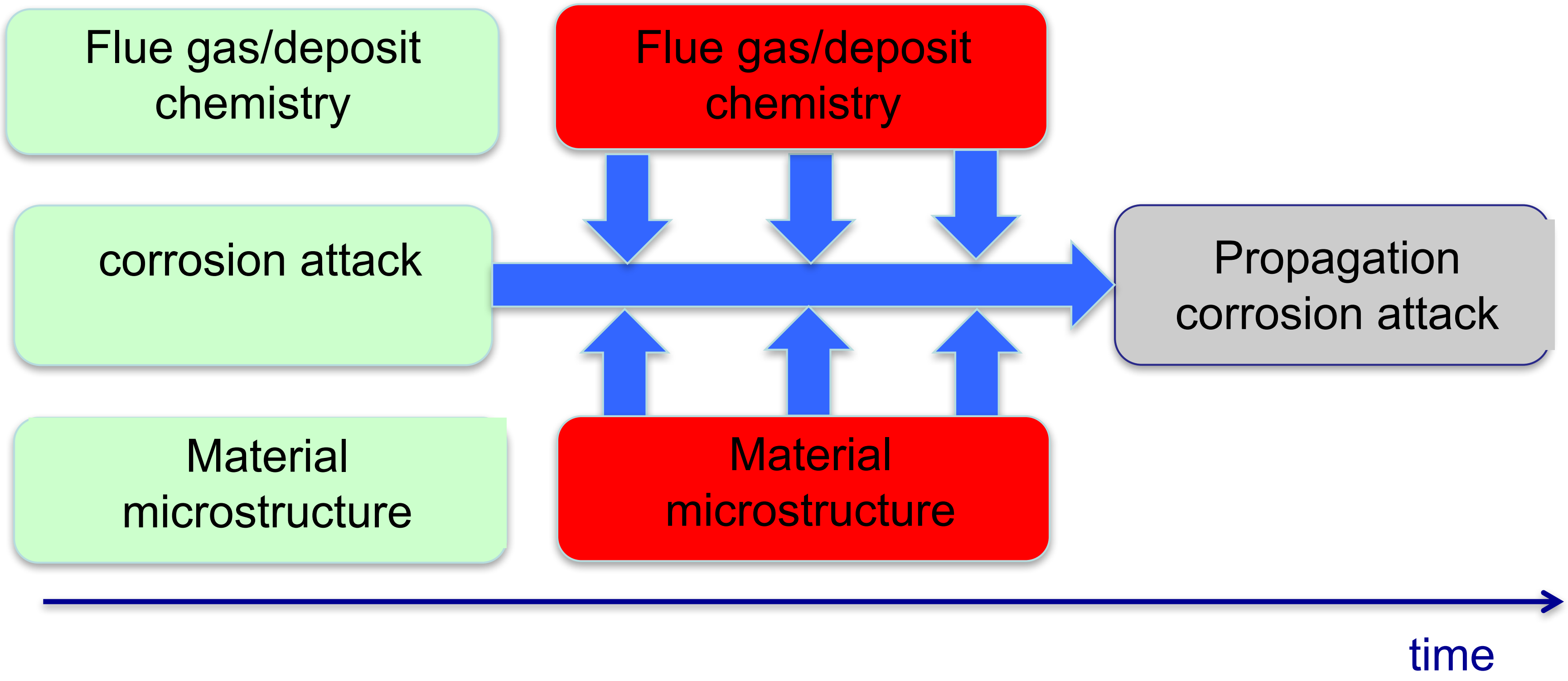
***Oxide scales**, **alloy microstructure** and **thick deposits** from the past influencing future corrosion attack.*

Flue gas from non-corrosive fuel

Flue gas from a corrosive fuel

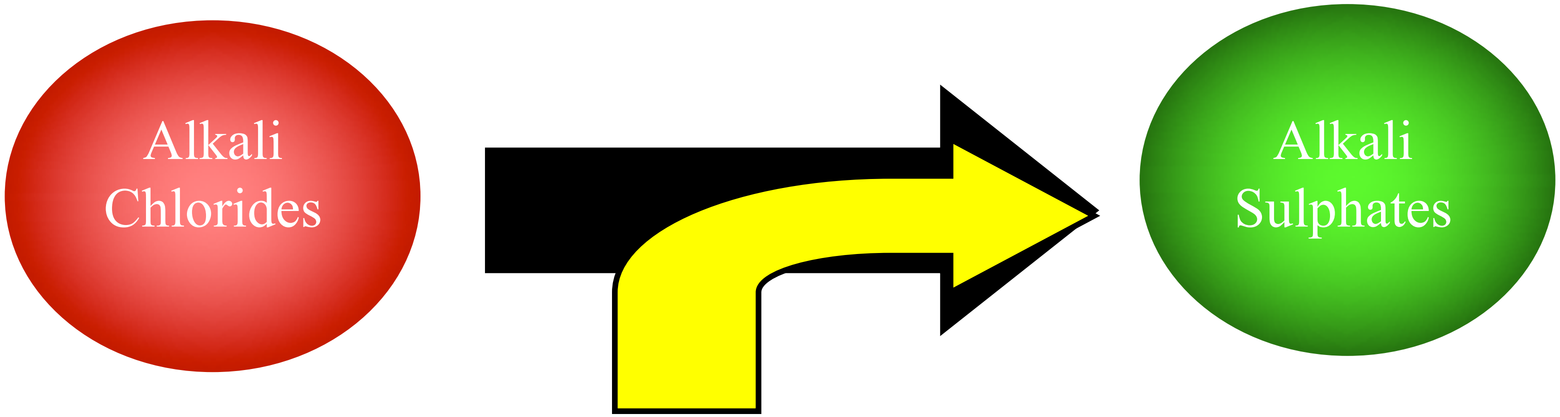


What are the challenges in studying the propagation?



A strategy for mitigating the alkali induced corrosion of high temperature steels

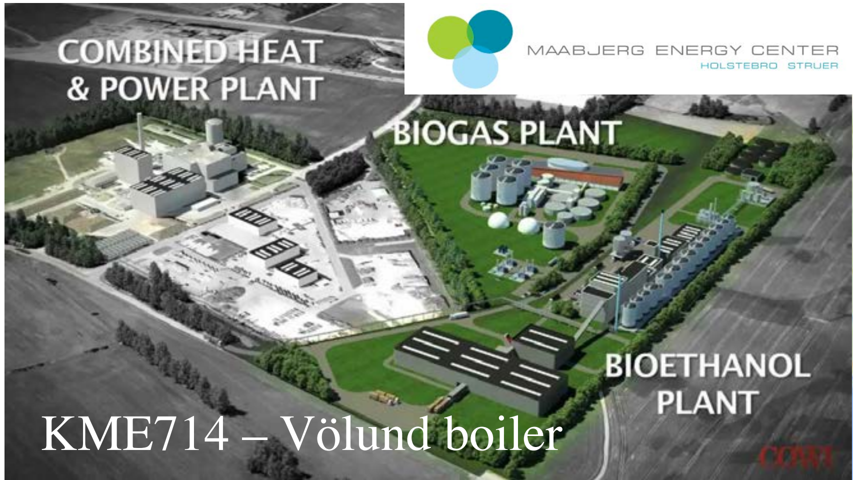
Change the fireside environment by means fuel additives



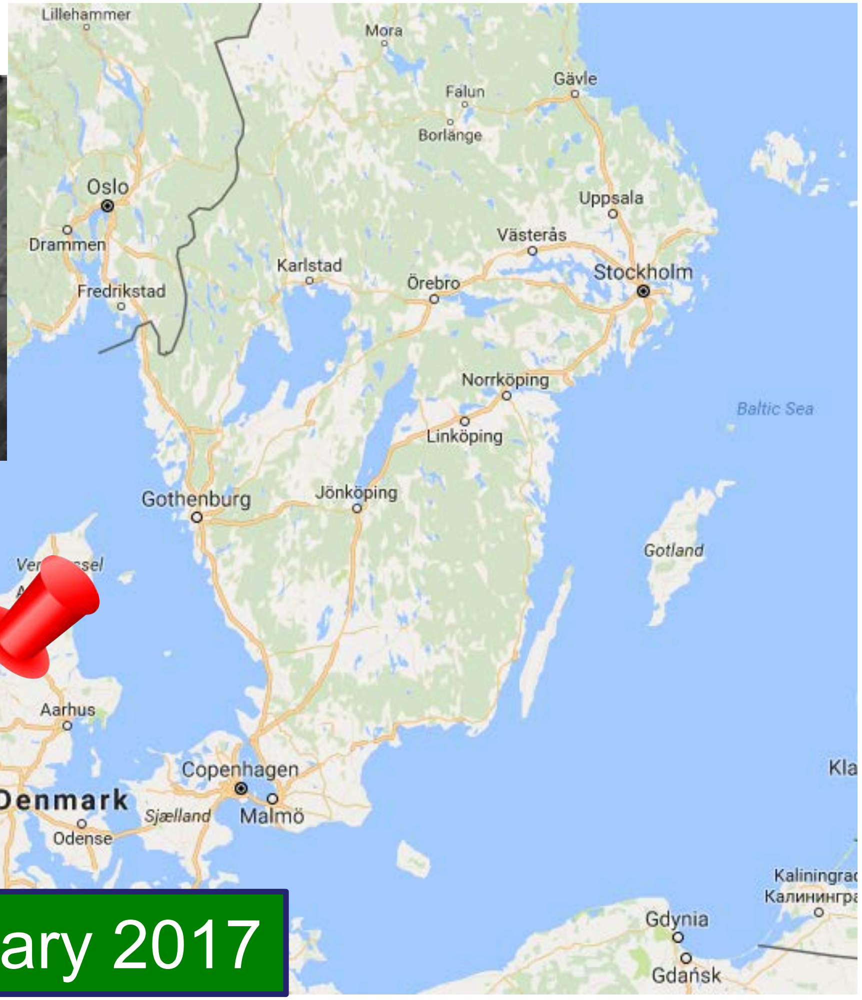
Adding sulfur or sulfur-rich fuels

- Elemental sulfur
- Ammonium sulphate
- Sulfur recirculation
- Municipal sewage sludge

Autumn-Winter 2016/17
Field exposures



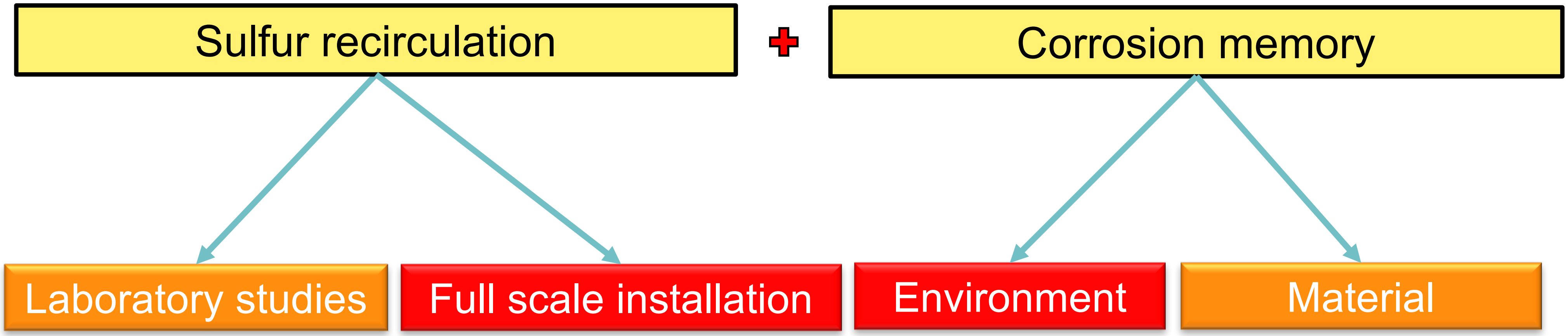
KME714 – Völund boiler



November 2016 - February 2017

Overall Goal of KME714

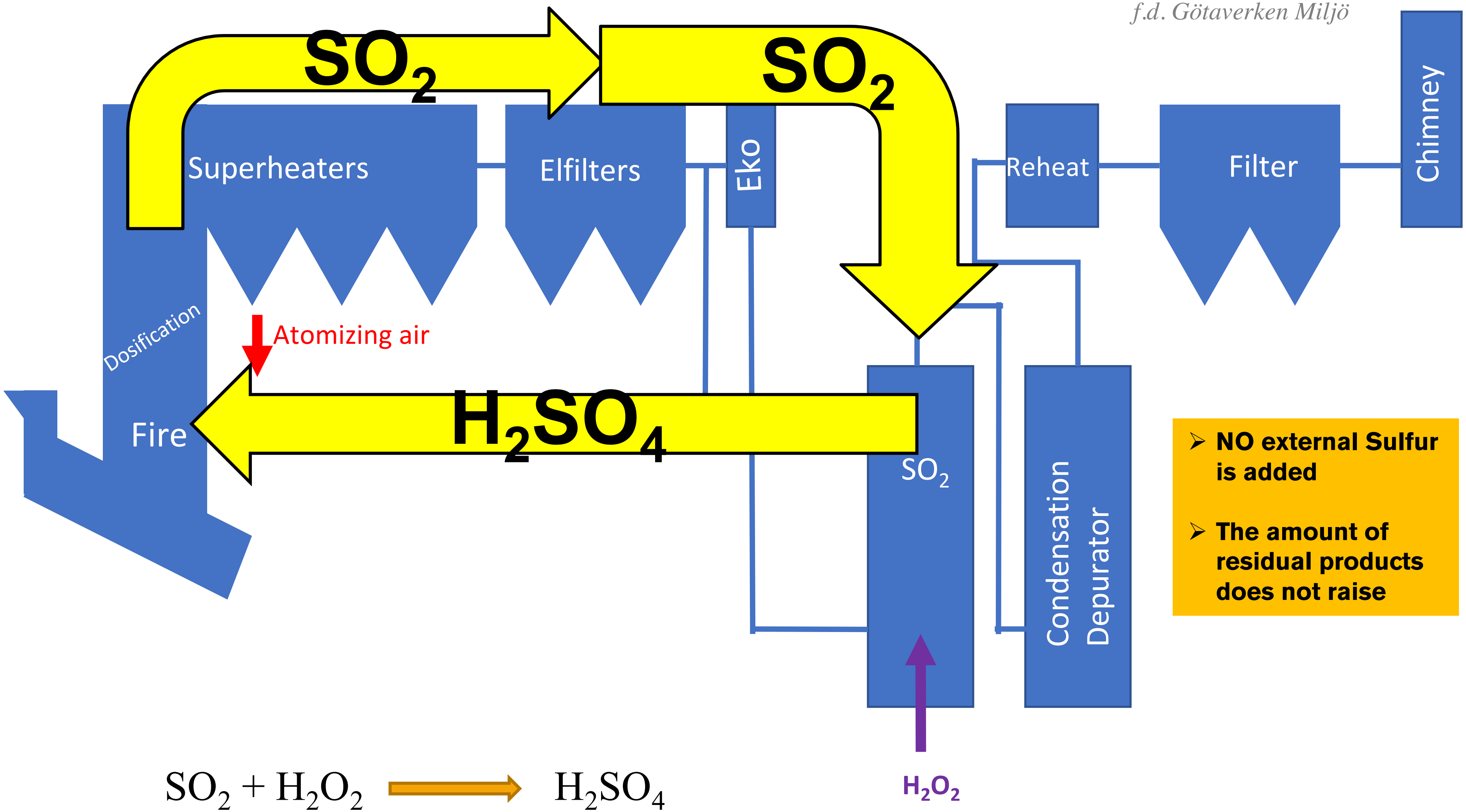
- Research strategy and correlation to KME goals



KME goals:

- Increase green electricity production from combustion of biomass and waste
- Improved fuel flexibility
- Improved material design/selection

B&W vølund
f.d. Götaverken Miljö

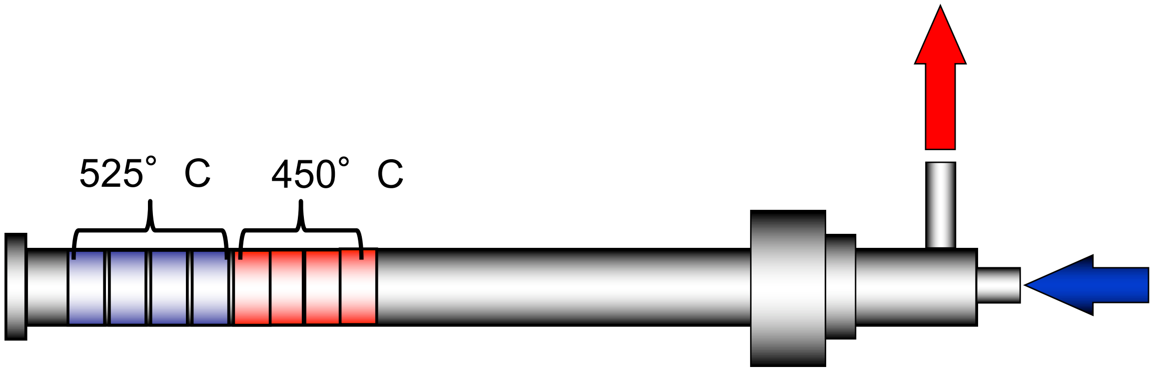


- **NO external Sulfur is added**
- **The amount of residual products does not raise**

$$SO_2 + H_2O_2 \longrightarrow H_2SO_4$$

Experimental matrix
Materials

November 2016 – February 2017



- 13CrMo4-5
- Sanicro 28
- 310
- 347H

525°C

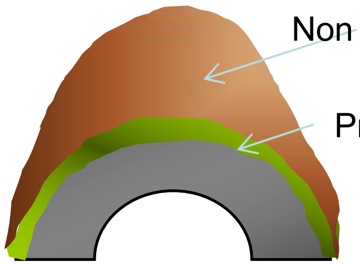
- 13CrMo4-5
- Sanicro28
- 310
- 347H

450°C

Modera
(Sulfur r

rosive
added)

Reference probe



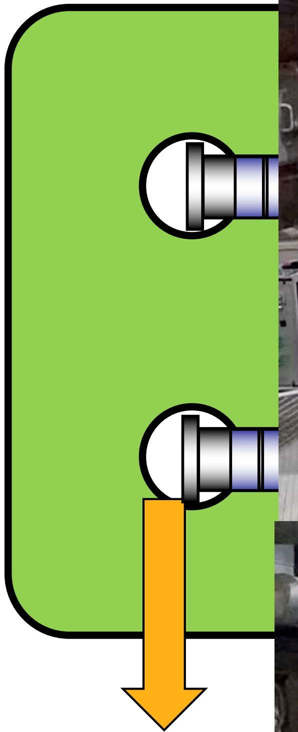
- TP347H (reference)
- 310
- Sanicro 28
- 13CrMo 4-5

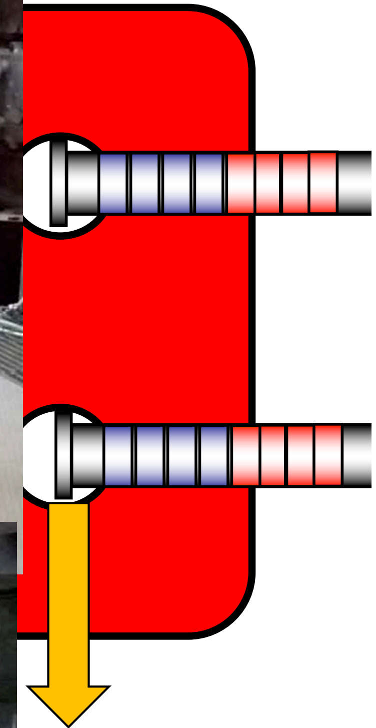
Reference probe

?

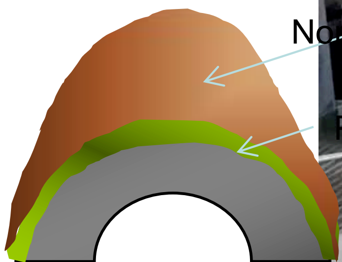
Moderate corrosive
(Sulfur recirculation)

Highly corrosive
(No-sulfur added)



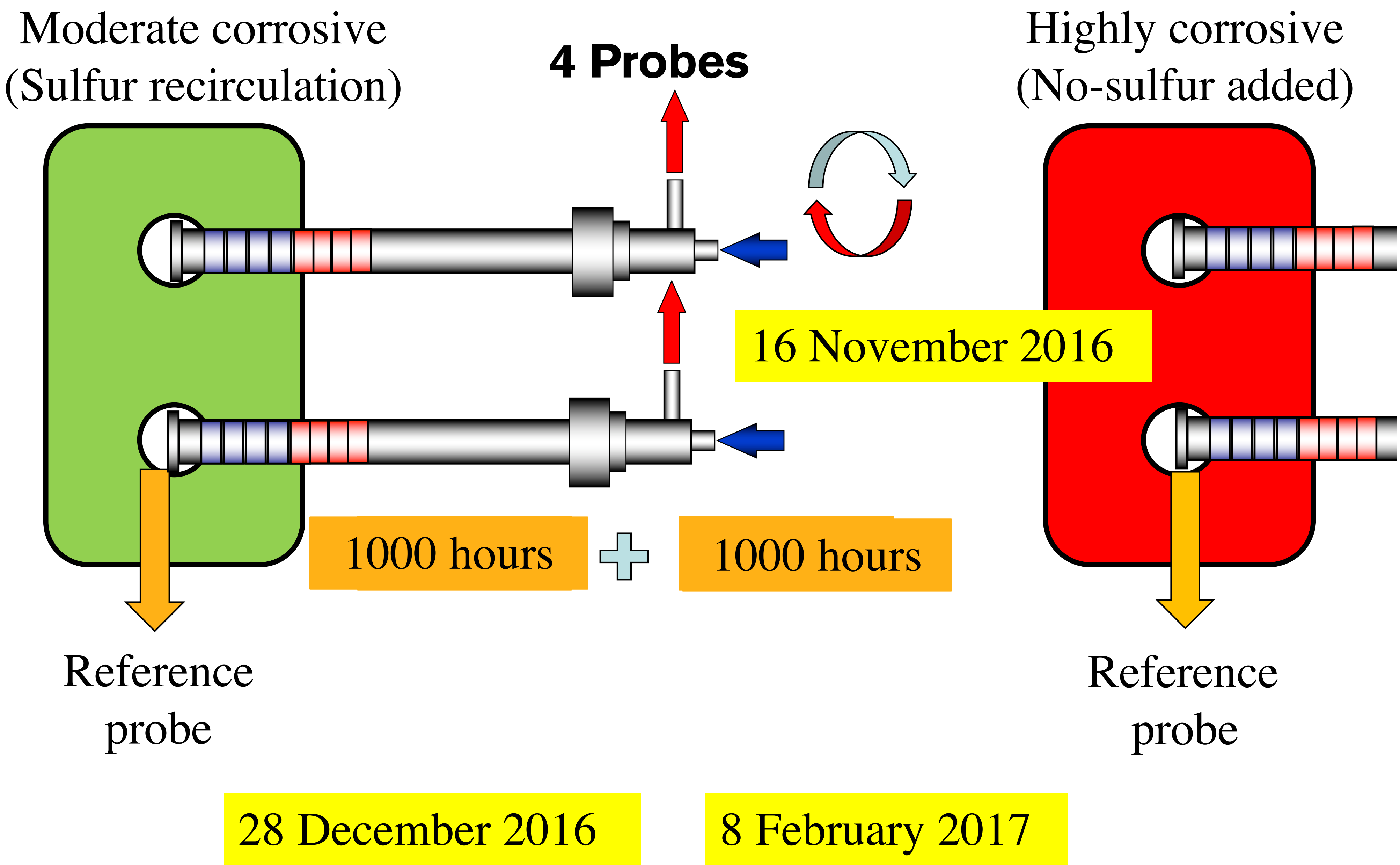


Reference
probe



ference
robe

?


Moderate corrosive
(Sulfur recirculation)
4 Probes
Highly corrosive
(No-sulfur added)
16 November 2016
1000 hours
1000 hours
Reference
probe
Reference
probe
28 December 2016
8 February 2017

Characterization

Ongoing

- Ion Chromatography (IC)
- Material loss
- SEM/EDX
- XRD

Overall Goal of KME714

- Research strategy and correlation to KME goals

Sulfur recirculation + Corrosion memory

- Sulfur recirculation
  - Laboratory studies
  - Full scale installation
- Corrosion memory
  - Environment
  - Material

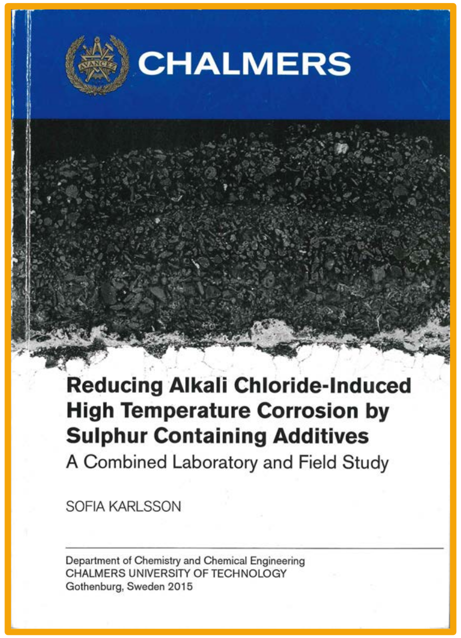
KME goals:

- Increase green electricity production from combustion of biomass and waste
- Improved fuel flexibility
- Improved material design/selection

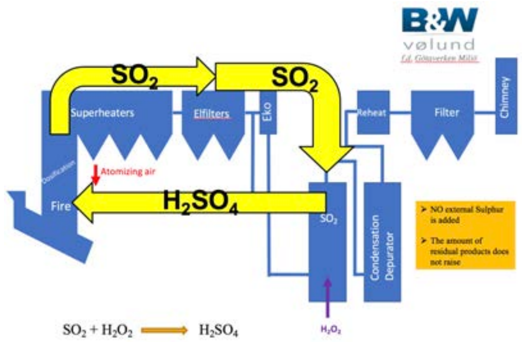
Research strategy

Fundamental research

Corrosion mechanisms


CHALMERS
Reducing Alkali Chloride-Induced High Temperature Corrosion by Sulphur Containing Additives
A Combined Laboratory and Field Study
SOFIA KARLSSON
Department of Chemistry and Chemical Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2015

Fundamental understanding of the corrosion process in boilers



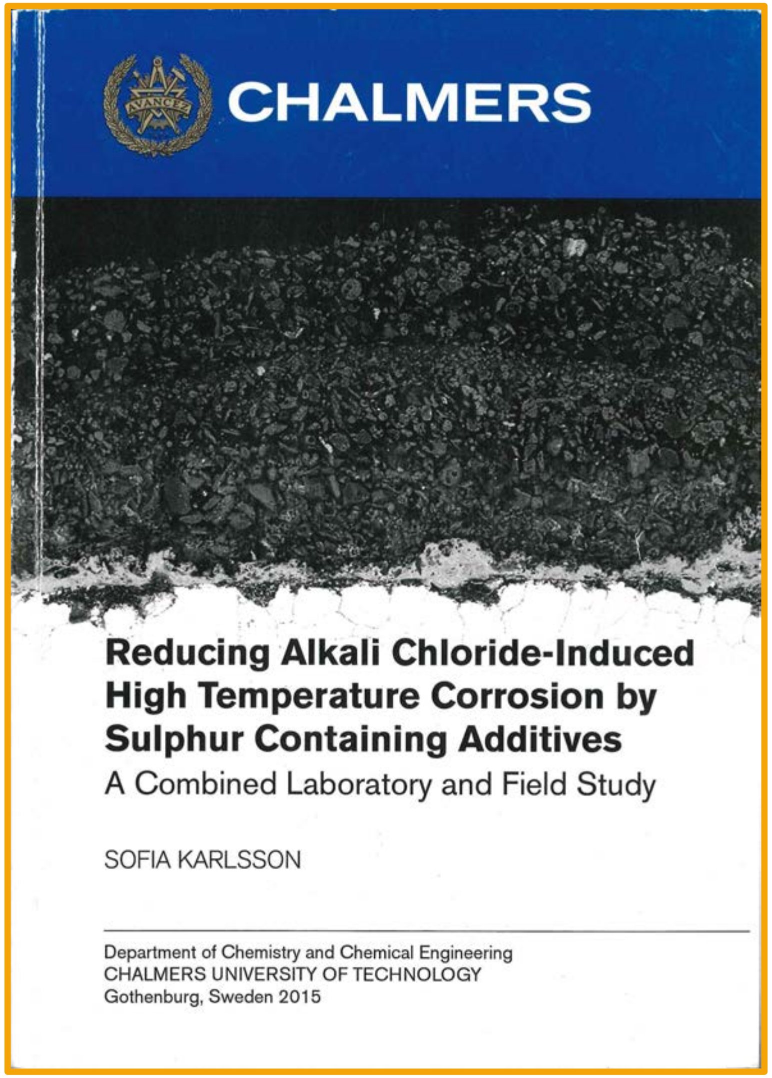
Effects of corrosion

Applied research

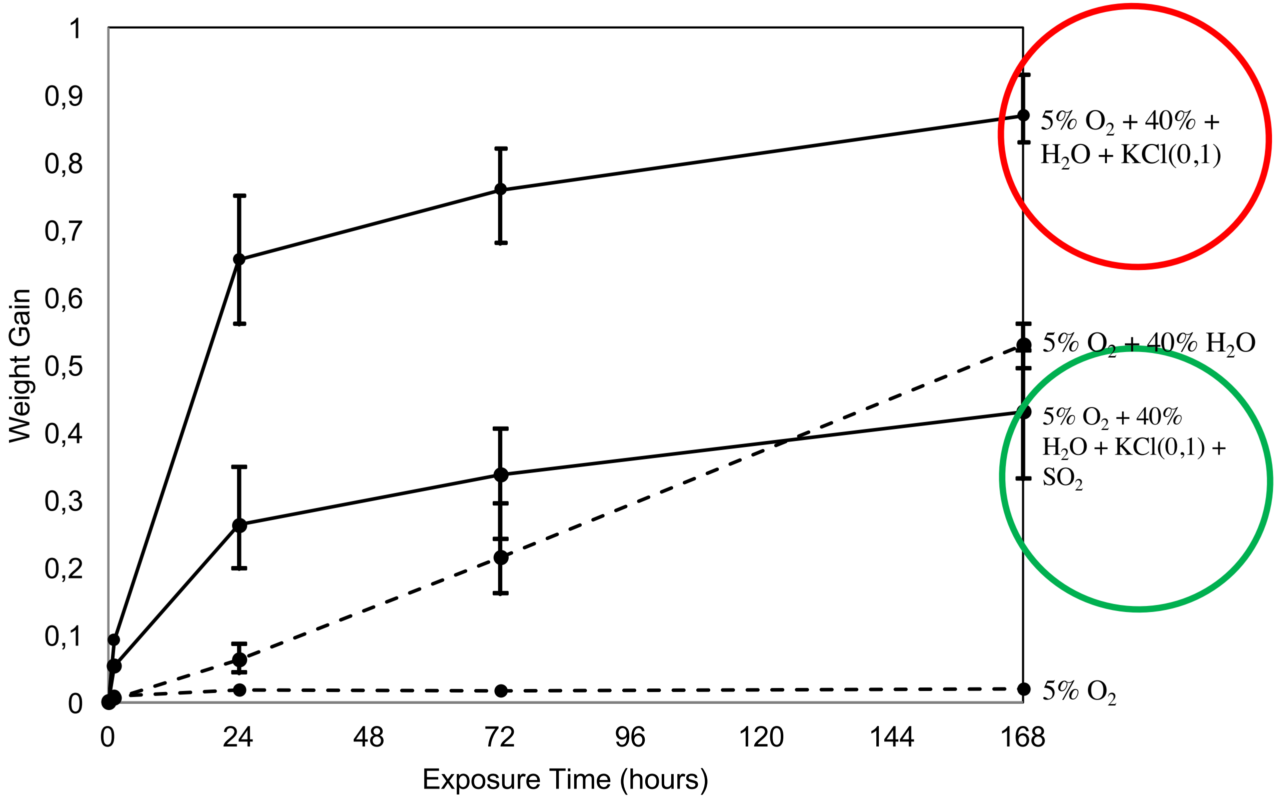
Laboratory studies

Field studies

The effect of SO_2 on KCl induced high temperature corrosion of stainless steel



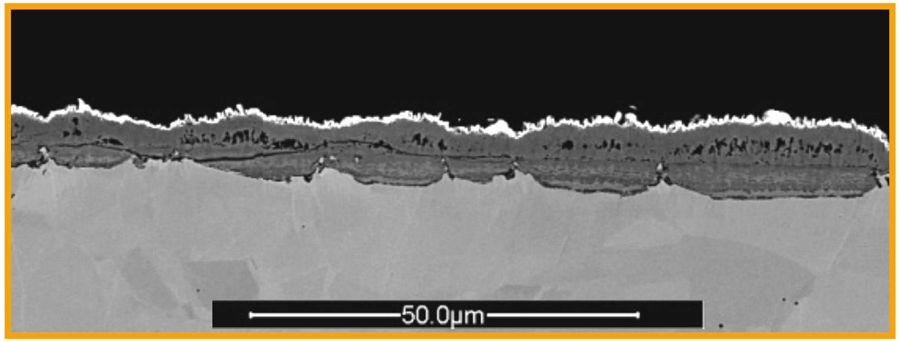
The effect of SO_2 on KCl induced high temperature corrosion of stainless steel



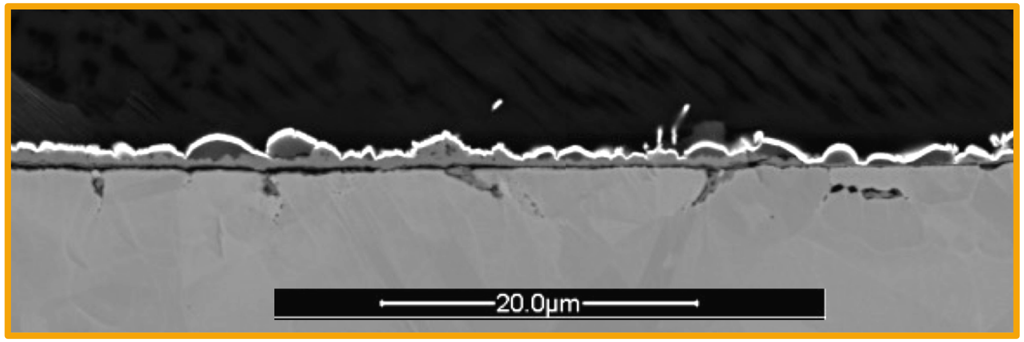
The effect of SO_2 on KCl induced high temperature corrosion of stainless steel

Cross section BSE

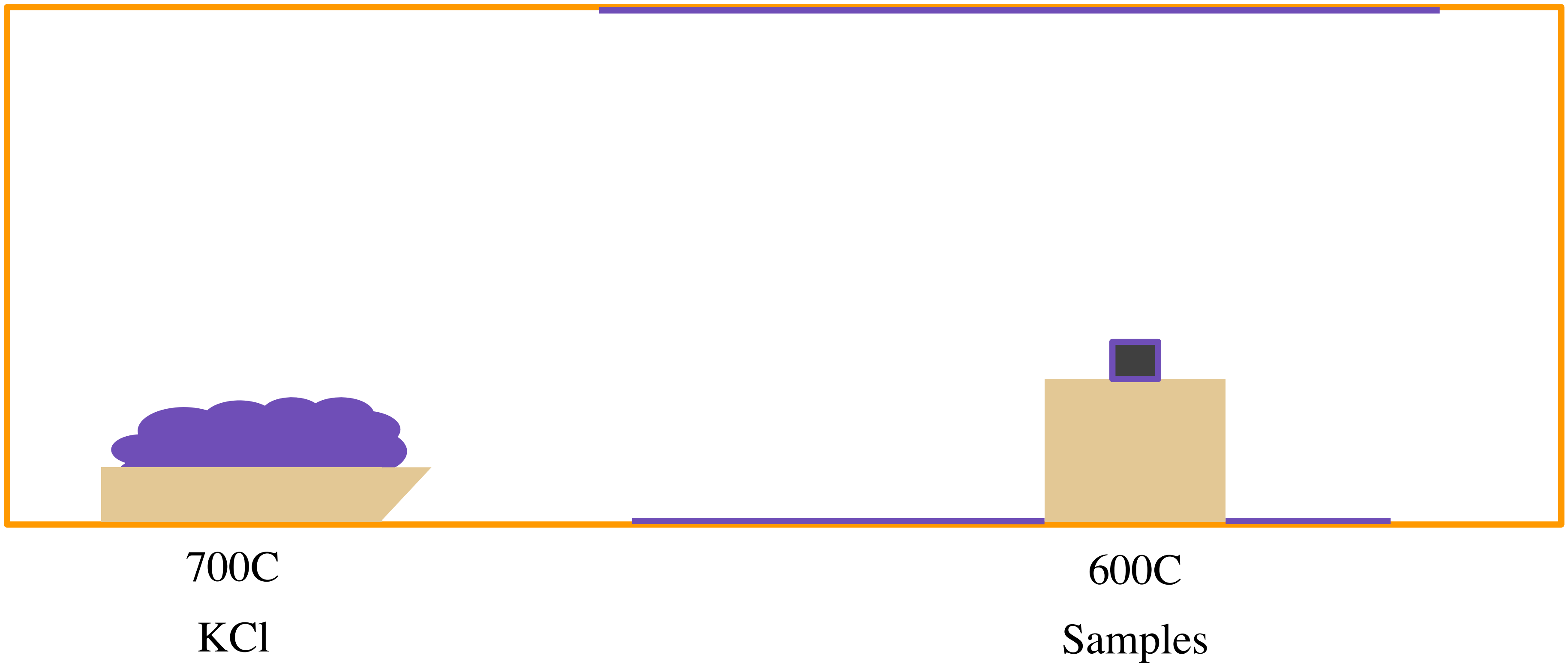
Without SO_2



With SO_2

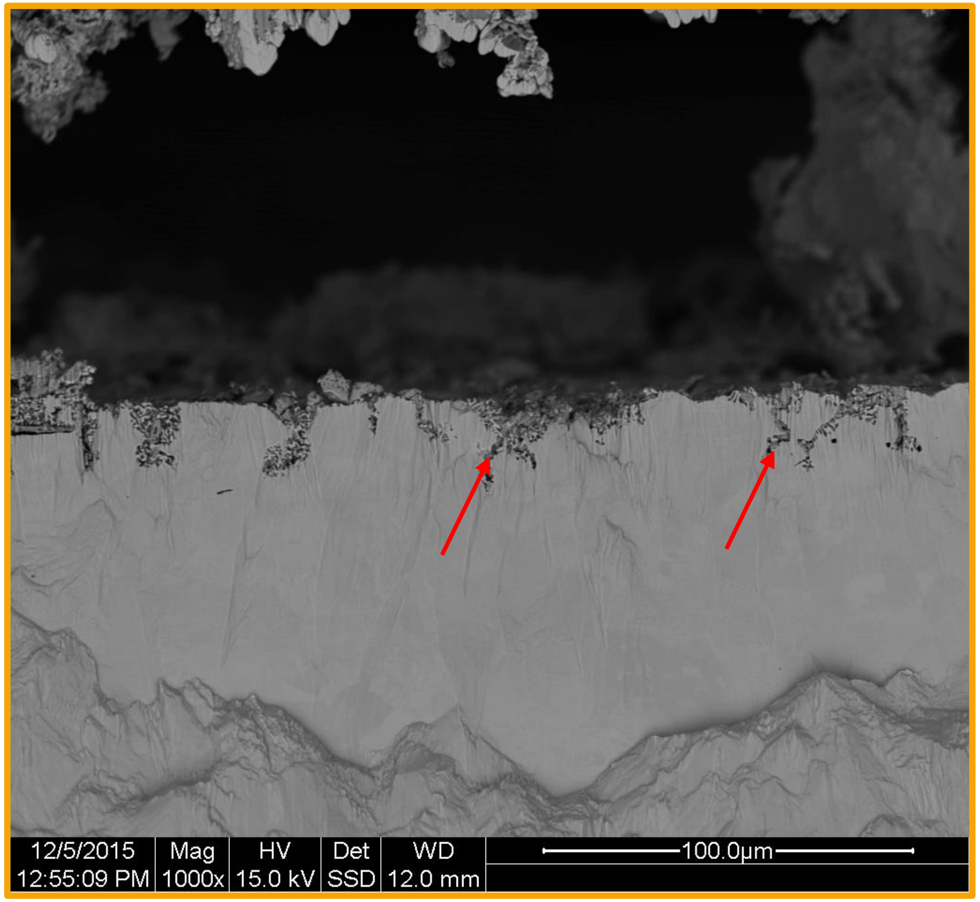


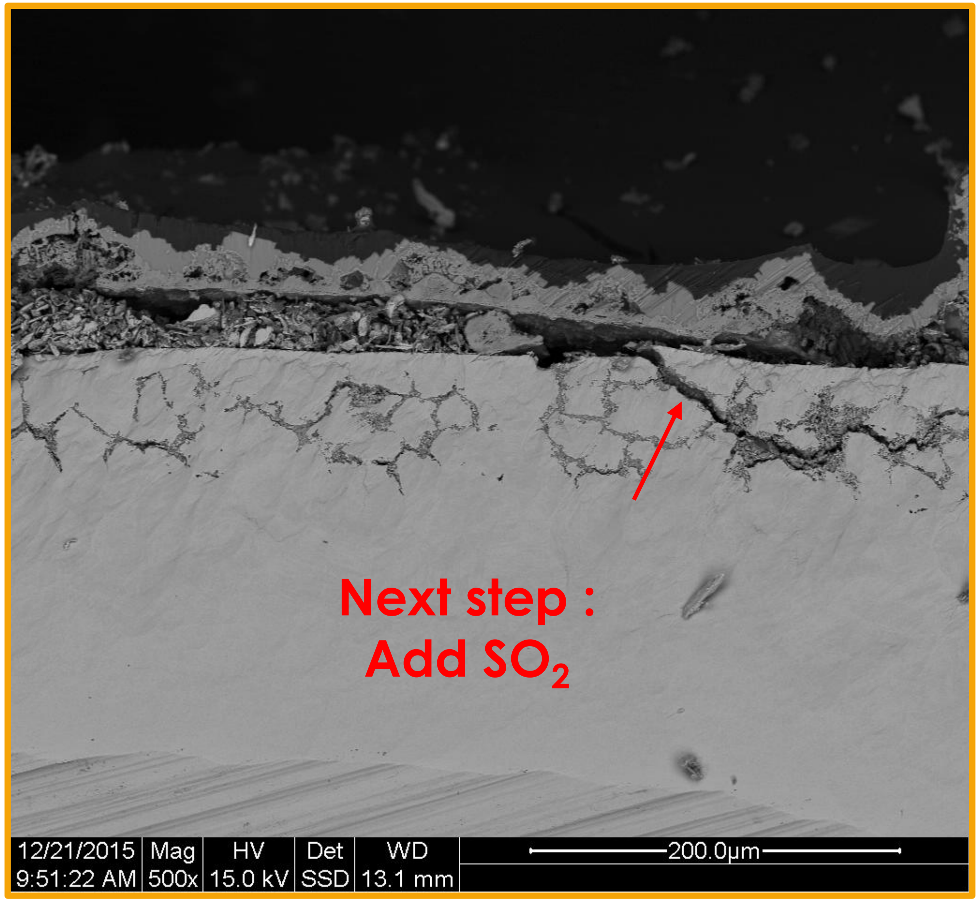
KCl added continuously



Regions with large amounts of KCl

Cross-section





Overall Goal of KME714

- Research strategy and correlation to KME goals

Sulfur recirculation + Corrosion memory

Laboratory studies | Full scale installation | Environment | Material

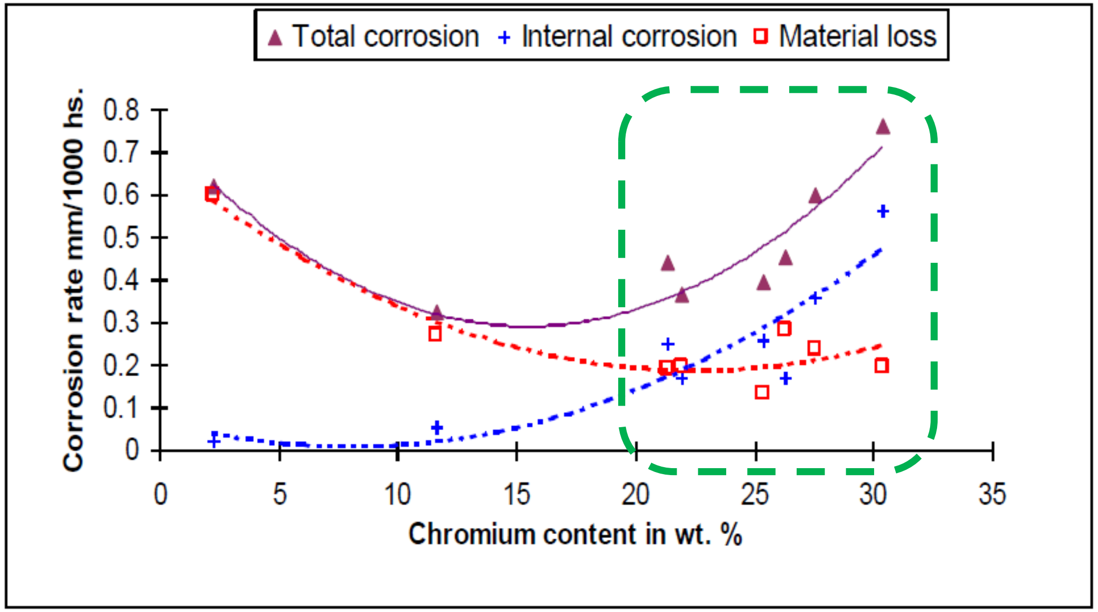
KME goals:

- Increase green electricity production from combustion of biomass and waste
- Improved fuel flexibility
- Improved material design/selection

Corrosion and steel microstructure

Controlled laboratory investigations (DTU), Investigation of field samples (DTU/DONG)

Background: **Findings for corrosion rates of materials with different Cr-content**

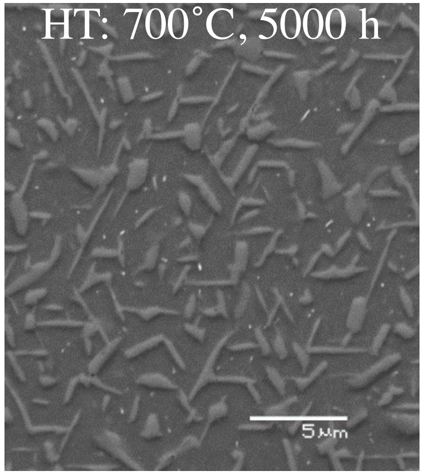


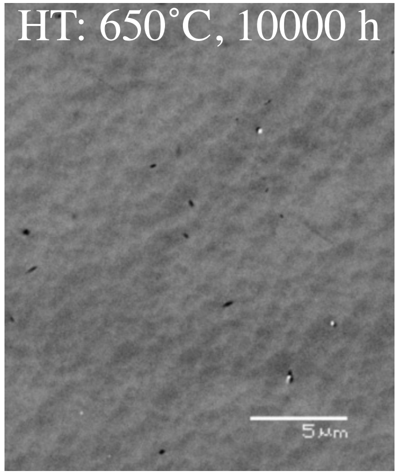
- **High Cr** content increases **internal corrosion** (blue line).
- **Low Cr** content gives high **material loss** (red line).
- Minimum in total corrosion lies at 15-18wt% Cr (purple line)

Is the increased internal corrosion only due to Cr-content or also the distribution of Cr?

(at high Cr content extensive precipitation can occur)

Controlled laboratory corrosion exposures of modified AISI310 (24 wt% Cr) steel in different heat treatment conditions





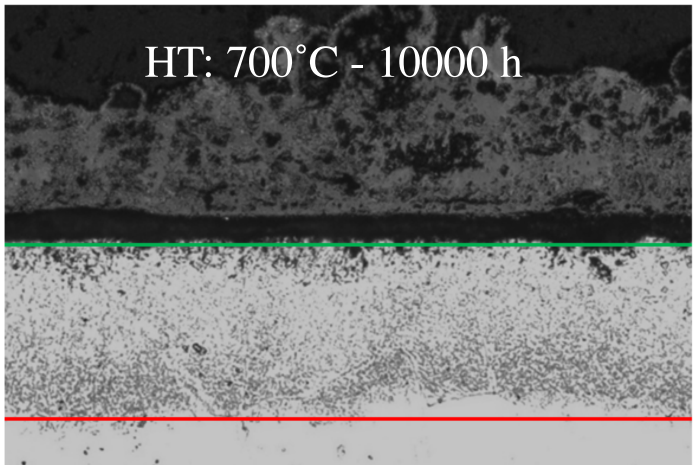
Heat treatment at 700˚C leads to heavy σ-phase precipitation. At slightly lower temperature no precipitation occurs even after longer exposure times

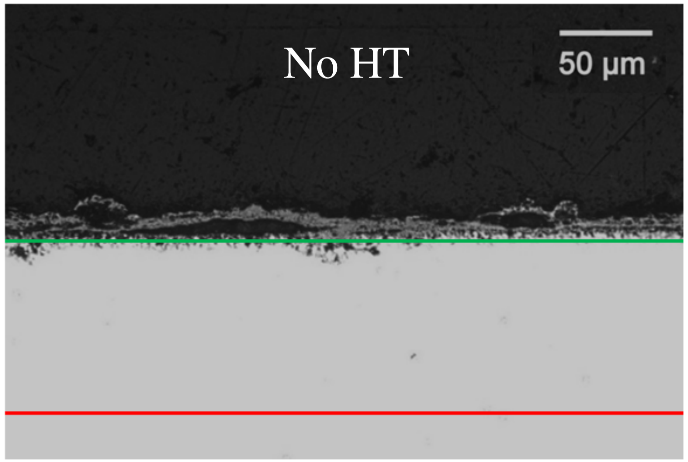
↓

Possibility to corrosion test the same material below 650˚C with very different precipitate distribution

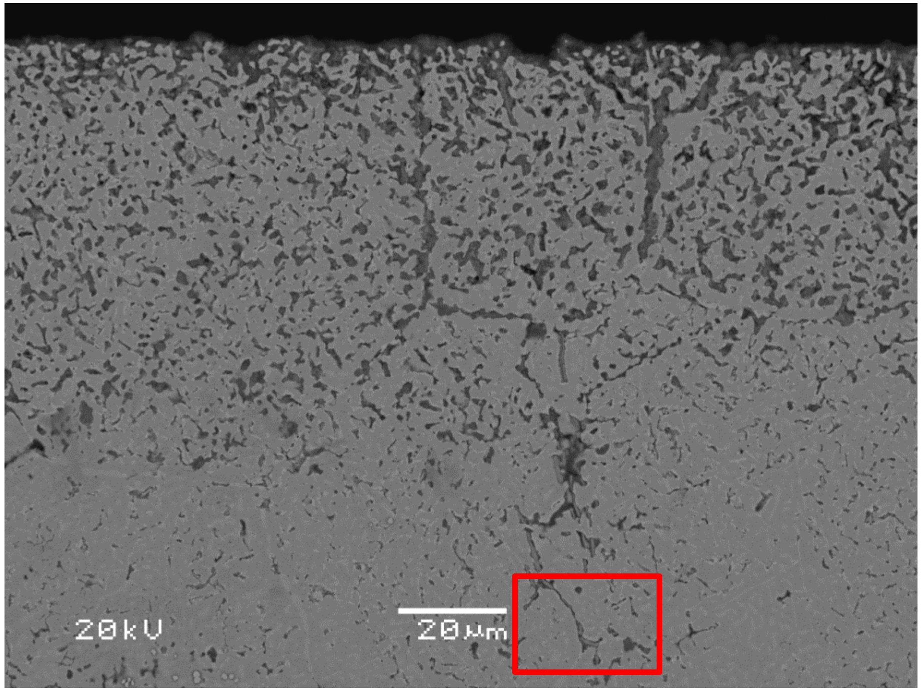
Corrosion testing:

Exposure: 15 % H_2O, 5 % O_2 and balance N_2, 600˚C, 168h, KCl Deposit

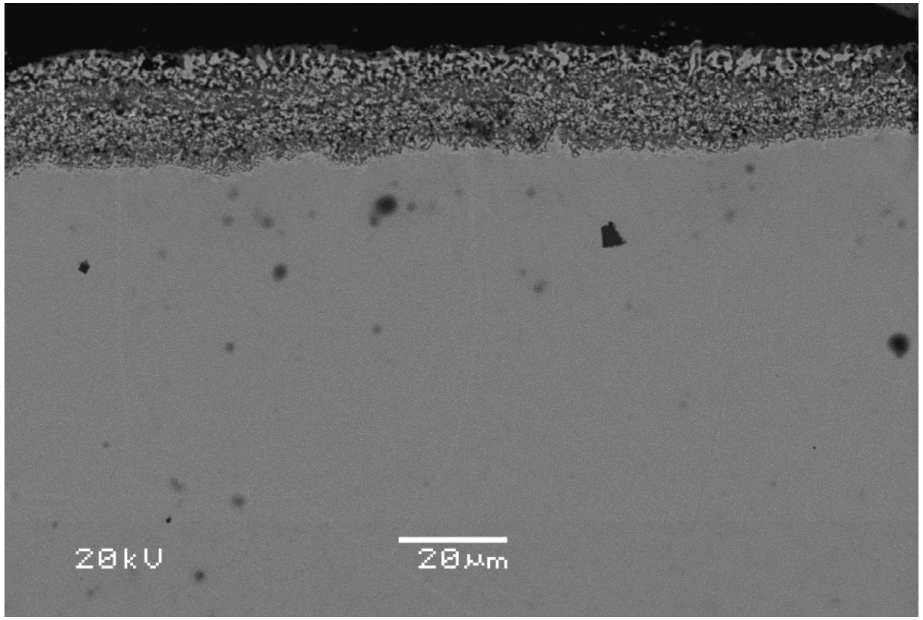


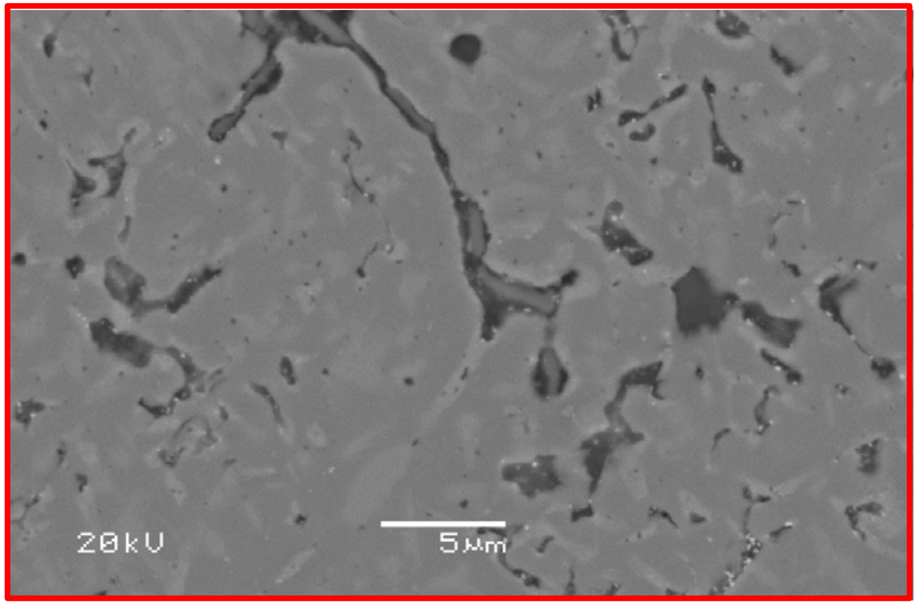


HT: 700˚C - 10,000 h



No HT





Clear influence of microstructure on corrosion attack

Heat treated material (Cr-rich σ phase) => Higher internal corrosion rate

Next steps:
In depth microstructural characterization

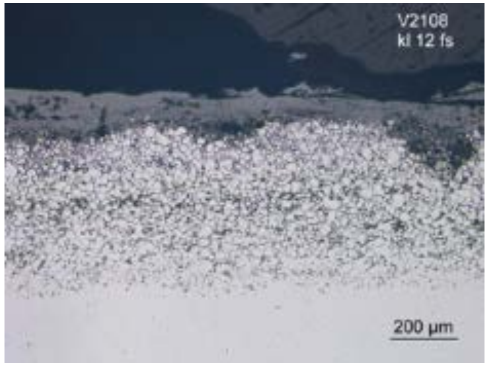
Laboratory exposure of TP347 in both aged and as received conditions

Investigation of field samples

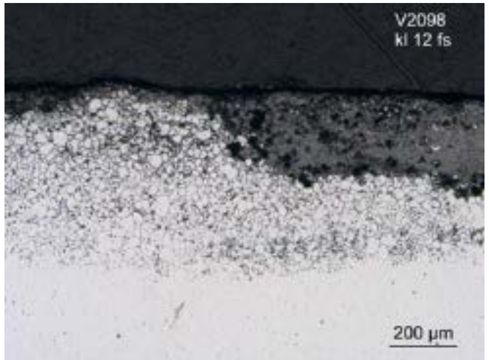
Fynsværket, unit 8, SH4:
different specimens with different temperature profiles – TP347H vs .Tempaloy AA1. Inlet and outlet, **17,000 hours**

Amagerværket 1:
Test section with different specimens 304H, 310, as well as 347H, **30,000 hours**

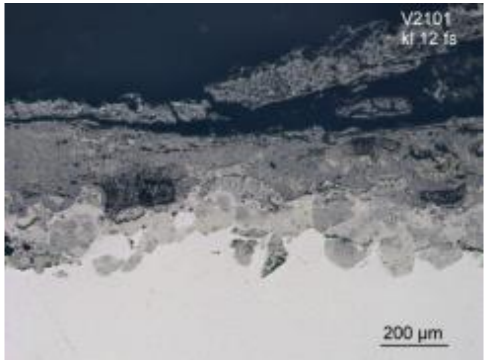
TP 347H FG



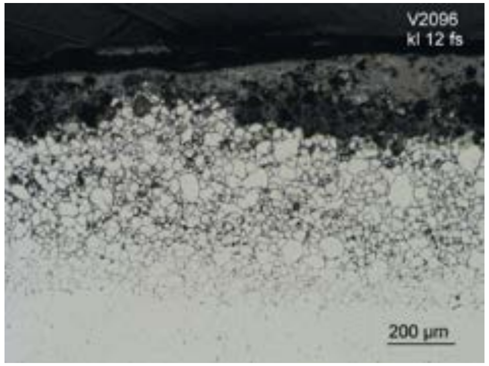
DMV Super 304H



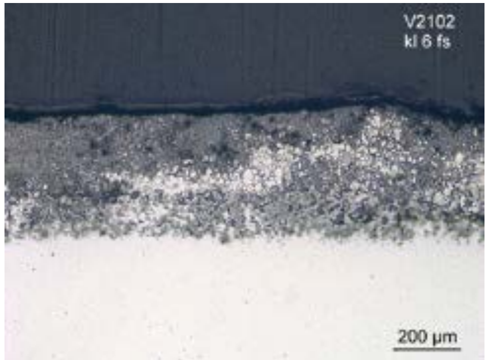
DMV 310N



DMV 347H FG



TX304HB



Work to be done:
- Comparison of microstructure for different steels and exposures in etched condition.
- Select specimens for more SEM analysis to understand corrosion attack.
- More advanced microscopy at areas at the corrosion front (FIB lift out and TEM).

Overall Goal of KME714

- Research strategy and correlation to KME goals

Sulfur recirculation + Corrosion memory

- Sulfur recirculation
  - Laboratory studies
  - Full scale installation
- Corrosion memory
  - Environment
  - Material

KME goals:

- Increase green electricity production from combustion of biomass and waste
- Improved fuel flexibility
- Improved material design/selection