Energiforsk

DTU

Increased flexibility and power-production from biomass through material development and corrosion prediction

Ørsted KANTHAL® Alleima Valmet

Energiforsk DTU

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Hanna Kinnunen (Valmet Technologies Oy)
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Goal

The overall goal of the project is to increase the efficiency, flexibility and predictability of power generation from biomass.

- Enabling these power generating processes to compete with the corresponding fossil fuel base processes
- Facilitate faster a materials selection process and increase the potential of biomass-fired power boilers.

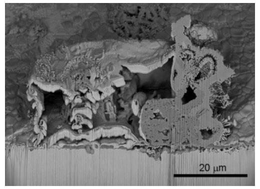
The scientific goals of the project:

- Determine the ***applicability*** and ***limitations of aluminium*** oxide forming materials for improved biomass conversion effect, as well as ***their comparison*** with ***existing materials***.
- Scale up ***lab-probe-fixed installation*** tests - predict impact of e.g. material and temperature on lifetime of key components. Implement ***thermodynamic-kinetic modelling*** of oxidation in complex environments.

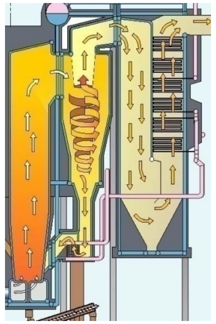
Research strategy – a two pronged approach

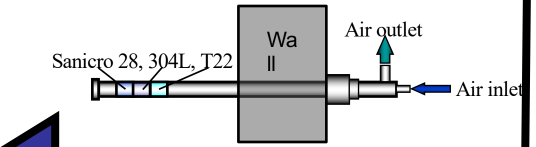
Fundamental research

Corrosion mechanisms



Fundamental understanding of the corrosion process in boilers





Applied research

Effects of corrosion

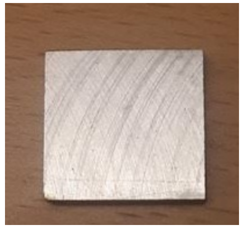
Laboratory studies

Field studies

Collaboration with HTC1a
Teamwork 2

Strategy

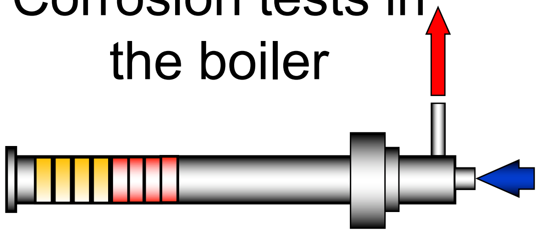
Ranking model alloys

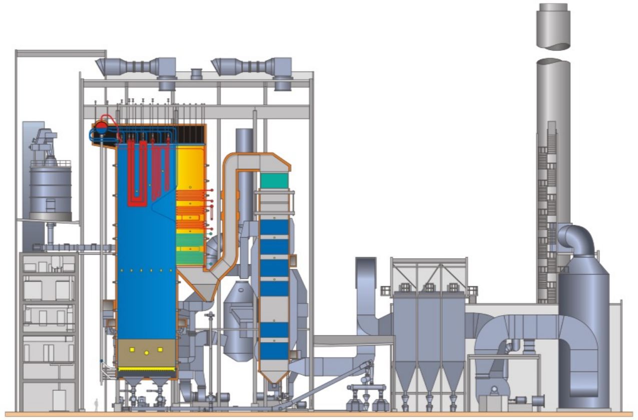


Lab – collaboration
with **HTC1a**

Most promising model alloys

Corrosion tests in
the boiler





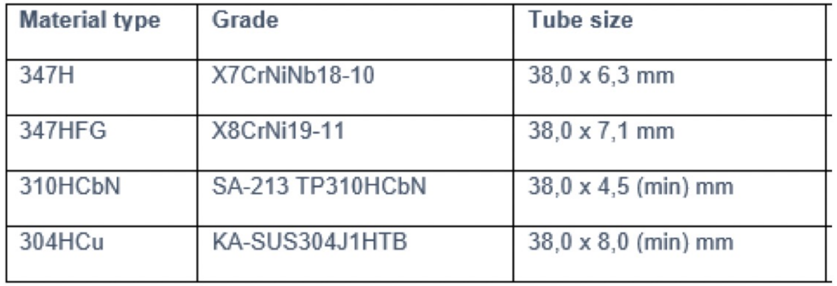
Side view illustration of ASV6Bio

- Characterize the deposit at different positions/temperatures
- Expose the most promising model alloys (168h/2000h)
- Compare oxidation resistance with existing materials

New boiler - Superheater test tube installations

- Four test tube materials installed to the tertiary superheater
- Straight tubes, hottest part of the tertiary superheater

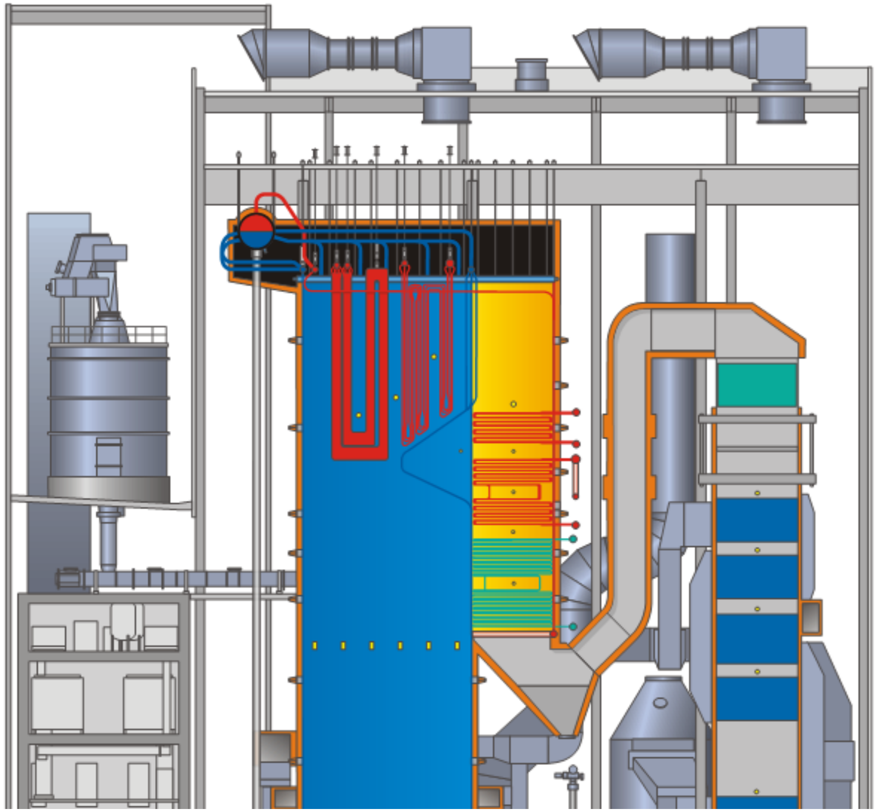
Material temperature of ~ 540 °C



Material type	Grade	Tube size
347H	X7CrNiNb18-10	38,0 x 6,3 mm
347HFG	X8CrNi19-11	38,0 x 7,1 mm
310HCbN	SA-213 TP310HCbN	38,0 x 4,5 (min) mm
304HCu	KA-SUS304J1HTB	38,0 x 8,0 (min) mm

Removed in July 2022

Estimated exposure time: 22000 hours

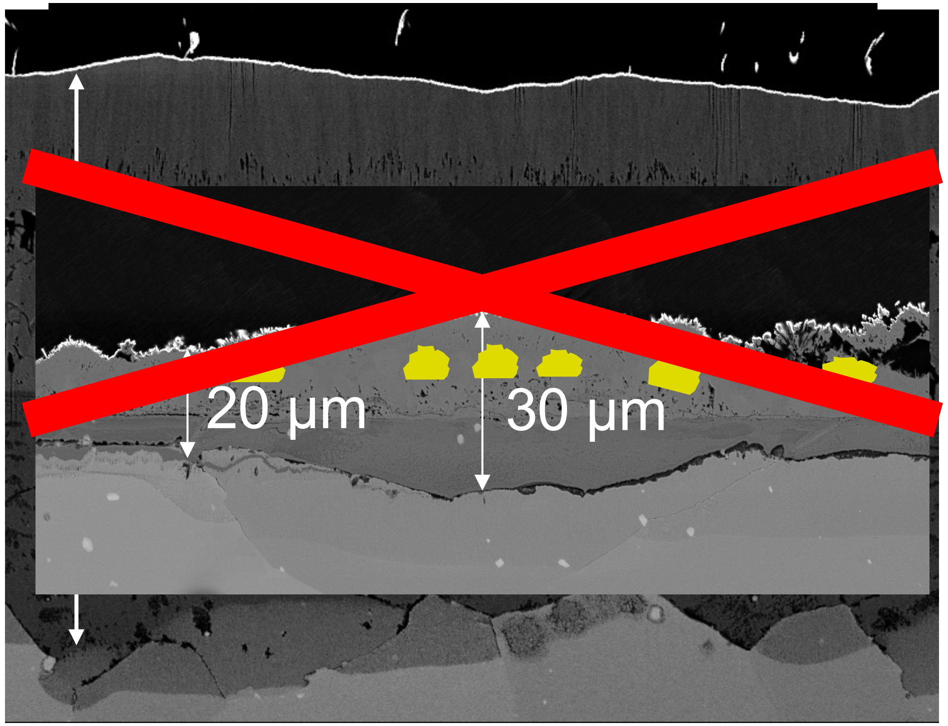


Corrosion regimes

- Primary corrosion regime
  - Cr- and or Al-rich corundum-type (M_2O_3) oxide scales (chromia/alumina) – Primary protection of an alloy
  - Slow-growing

Breakaway oxidation → Rapid material degradation → Not desirable

- Secondary corrosion regime
  - Fe-rich multi-layered oxide scale – Secondary protection of an alloy
  - Fast-growing

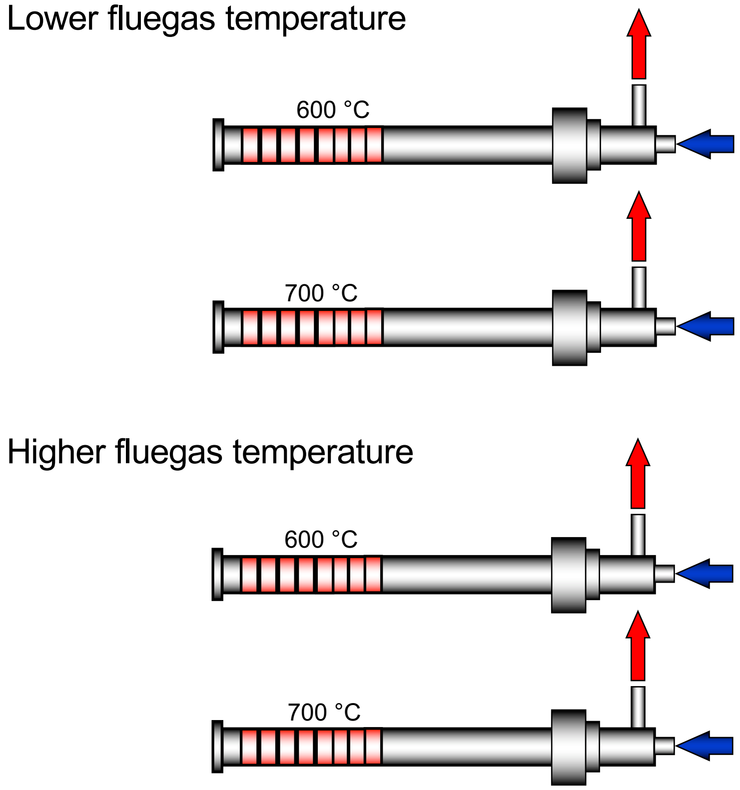


Probe exposures - 168h and 2000h

SKV402 and ASV06

Probe exposure - SKV402 (168 hours)

Main fuel: Wood chips



- 347H
- 310
- Sanicro 25

Commercial stainless steels

- 347H with thermally sprayed with EF101 (Fe12.4Cr(5.6-6.0)Al2.4Si)

- Kanthal EF101 (Fe12.4Cr3.7Al1.3Si)

Newly developed FeCrAl alloy

- Fe10Cr4Al0Si
- Fe10Cr4Al1Si
- Fe10Cr3Al2Si

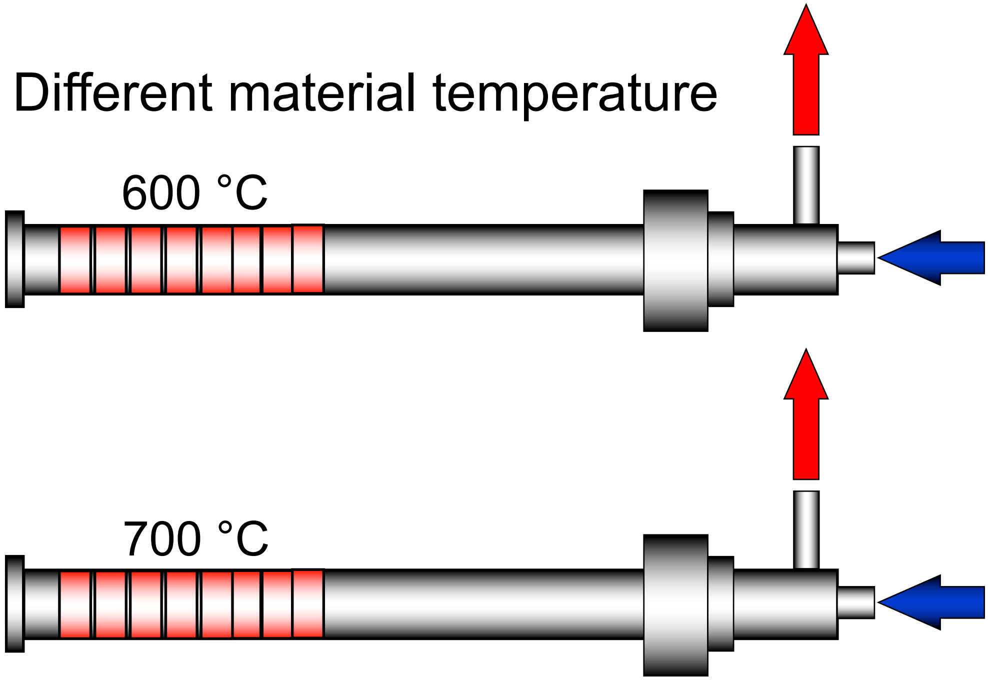
FeCrAl model alloys

Probe exposure - ASV06 (2000 hours)

Main fuel: Wood chips

Reduced the number of sample probes (two probes)

Different material temperature



Use the same alloy matrix:

- 347H
- 310
- Sanicro 25
- 347H with thermally sprayed with EF101 (enhanced)

- EF101 - Fe12.4Cr3.7Al1.3Si
- Fe10Cr4Al0Si
- Fe10Cr4Al1Si
- Fe10Cr3Al2Si

Summary of results

- Thickness measurements performed before/after exposure
    - Material loss negligible

- Material temperature
    - 600 °C
    - 700 °C
- Flue gas temperature
    - Lower
    - Higher
- Alloy composition
    - Stainless steels
    - FeCrAl alloys
    - Coating

Ion chromatograhy

- In general, the **FeCrAl alloys behaved better** than the stainless steel
    - Better at **withstanding presence of Cl**
- Indication of **improved corrosion behavior** upon **Si-addition**
- **EF101 coating** showed **great corrosion resistance**

V06

- → **Very mild environment**

SEM/EDX analysis

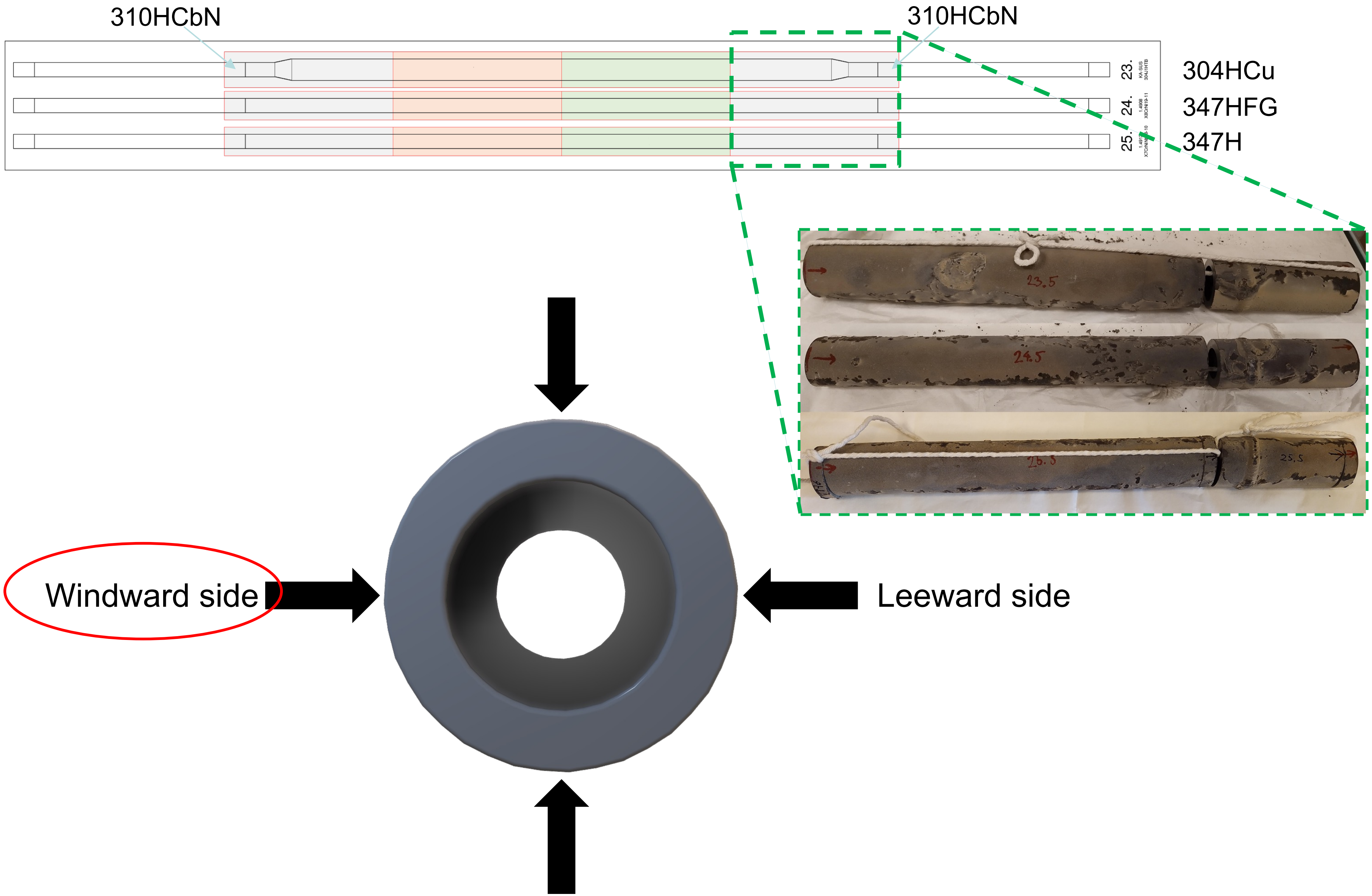
- **Indicates higher amount of Cl** in the deposit at **lower material temperature (SKV402)**
    - **Slightly higher** corrosion attack **at 600°C** compared to 700 °C

168h				
Alloy	Low fluegas temperature		High fluegas temperature	
	600C	700C	600C	700C
347H	Secondary	Majority Primary	Majority Secondary	Majority Primary
310	Majority Secondary	Majority Primary	50/50	Majority Secondary
Sanicro 25	Secondary	Majority Secondary	Secondary	50/50
EF101	50/50	Majority Primary	Majority Primary	Primary
Fe10Cr4Al0Si	50/50	Primary	Primary	Primary
Fe10Cr4Al1Si	Primary	Primary	Majority Primary	Primary
Fe10Cr3Al2Si	Majority Primary	Primary	Primary	Primary
347H with EF101	Primary	Primary	Primary	Primary

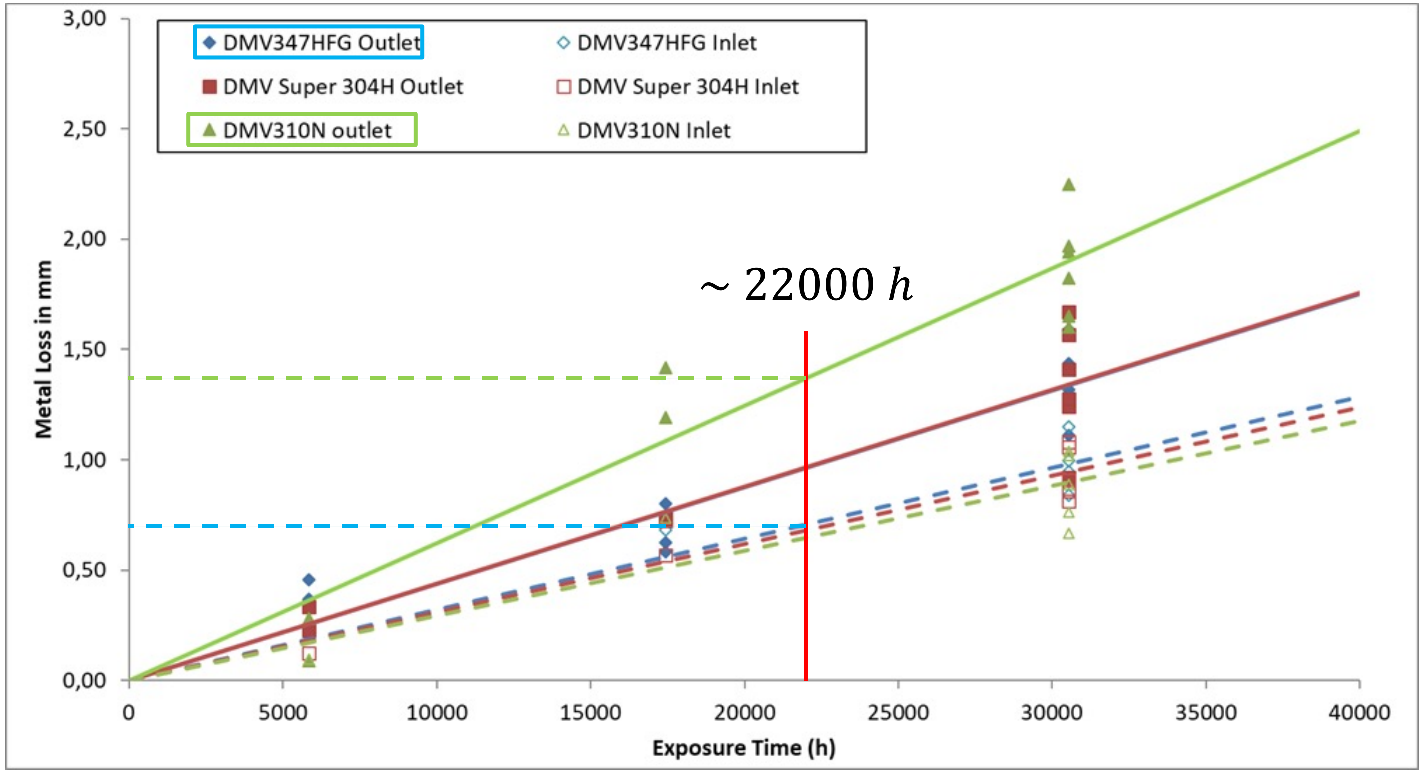
2000h		
Alloy	600C	700C
347H	Primary	50/50
310	Primary	Majority Primary
Sanicro 25	Majority Primary	Majority Primary
EF101	Primary	Primary
Fe10Cr4Al0Si	Primary	Primary
Fe10Cr4Al1Si	Primary	Primary
Fe10Cr3Al2Si	Primary	Primary
347H with EF101	Primary	Primary

Fixed installed tubes

(ASV06)


310HCbN
310HCbN
23.
24.
25.
304HCu
347HFG
347H
23.5
24.5
25.5
Windward side
Leeward side

Material	Inner corrosion layer	Internal corrosion	Precipitation zone	Metal loss
304HCu	5-20 µm	5-15 µm	15-20 µm	10-35 µm
347HFG	5-15 µm	3-6 µm	3-6 µm	8-21 µm
347H	5-15 µm	15-20 µm	15-25 µm	20-35 µm
310HCbN	3-10 µm	10-20 µm	10-15 µm	13-30 µm



From: Final report, ForskEL - 2015-1-12289, *Corrosion management in biomass firing*, September 2019. Available on request from jhald@dtu.dk

Metal loss in exposure tests at the suspension fired straw/wood pellet boiler Amager 1

Potential of increasing steam parameters

Predicting the corrosion rate

- Performed for both primary and secondary regimes
  - Primary: Chromia (600 ℃ and 700 ℃) and alumina (900 ℃)
  - Secondary: Iron oxide (540 ℃, 600 ℃ and 700 ℃)

- **Primary protection**
  - Chromia:
    - Thickness in nanometer range up to 2000 hours
  - Alumina:
    - Thickness in nanometer range up to 2000 hours

Agrees with observations

- **Secondary protection**
  - Iron oxide:
    - Observed thickness significantly lower than predicted
      - 540 ℃: 10 times lower than predicted
      - 600 ℃: Half of predicted
      - 700 ℃: 15 times lower than predicted

Other mechanisms in play

Thermo-Calc Software

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Acknowledgement

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