



KME-708/718

High temperature corrosion in used-wood fired boilers – fuel additives and coatings

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Background

Project KME718 builds on projects KME-508, KME-512 and KME-708 which for used-wood fired boilers have shown that:

- co-firing with treated sewage sludge can reduce water wall corrosion, at least in short-term tests lasting up to 14 h
- an FeCrAl alloy (Kanthal APMT) has excellent water wall corrosion resistance when tested as solid material, indicating its potential as a coating material

Projects goals – KME 718

- reduce operation and maintenance costs in boilers that burn predominantly used wood by the use of additives and coatings
- acquiring new knowledge from longer term studies on the effect of using sewage sludge and one alternative sludge
- acquiring in-depth knowledge on the corrosion behaviour of materials typically used for furnace walls with and w/o fuel additives
- investigating the corrosion properties of some new coating materials and their related performance with respect to furnace wall protection

RESULTS

FUEL QUALITY (KME708) & SLUDGE CAMPAIGN (KME718)

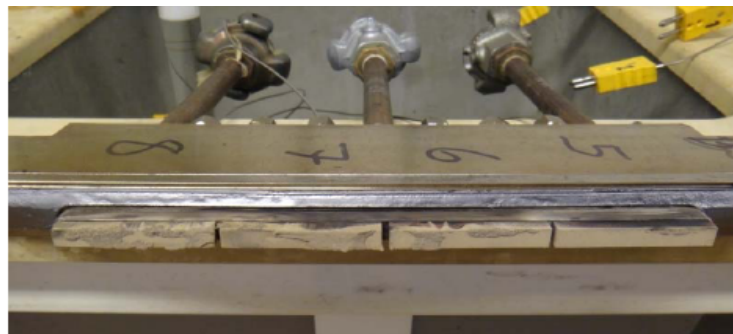
Experimental - Idbäcken BFB

Two test campaigns with two types of UW-fuel (KME708)

Two test campaigns with two types of sludge (KME718)*

- Two probes, nominally 350°C and 400°C at furnace wall.
- 2 specimens of 16Mo3 and 2 of Alloy 625 on each wall probe

WALL CORROSION PROBE TESTING



* Based on positive results from short term tests in KME508/KME708

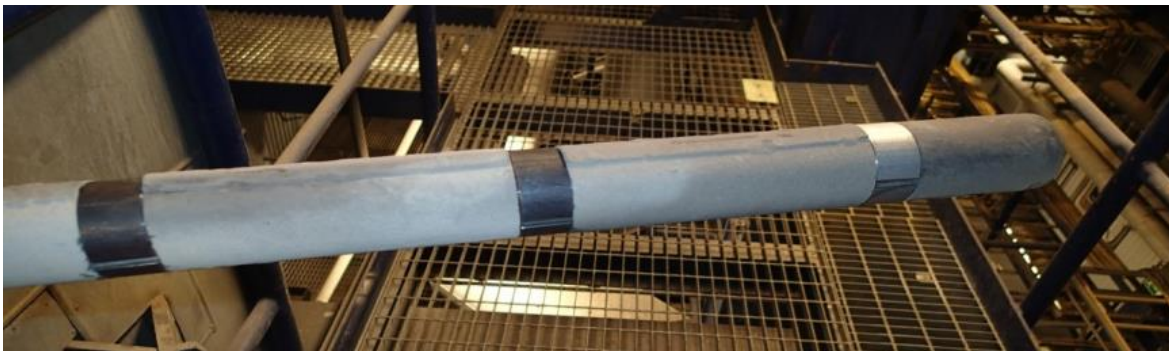
Experimental - Idbäcken BFB

Two test campaigns with two types of UW-fuel (KME708)

Two test campaigns with two types of sludge (KME718)

- 3 h exposure
- Superheater deposit probe. 3 hour test, 350,450,550°C
- Material: 2216 (350 and 450 °C) and 2352 (550 °C)

DEPOSIT PROBE TESTING IN SUPERHEATER REGION



Fuel compositions

- Compositions of the sludges are before mixing with the used wood.
- Fibre sludge from paper mill 18 wt % and digested sewage sludge 13 wt% in final fuel mixture

	UW -1	UW-2	Sewage sl	Fibre sl
Samples [number]	5	3	1	1
Moisture [as rec]	35	22	76	72
Ash [as rec]	3.6	5.8	8.3	2.7
S [% ds]	0.07	0.07	1.27	0.68
Cl [% ds]	0.13	0.20	0.05	0.03
K [mg/kg ds]	995	900	3 860	890
Na [mg/kg ds]	1 611	976	1 940	2 500
Al [mg/kg ds]	1 534	1 262	18 200	8 200
Ca [mg/kg ds]	4 044	5 117	23 400	9 200
Mg [mg/kg ds]	1 055	538	3 220	1 100
Si [mg/kg ds]	9 540	15 247	28 700	20 000
Cu [mg/kg ds]	46	45	259	17
Pb [mg/kg ds]	38	136	15	5
Zn [mg/kg ds]	398	122	524	170
P [mg/kg ds]	89	118	27 100	3 200



Used wood no. 1



Used wood no. 2



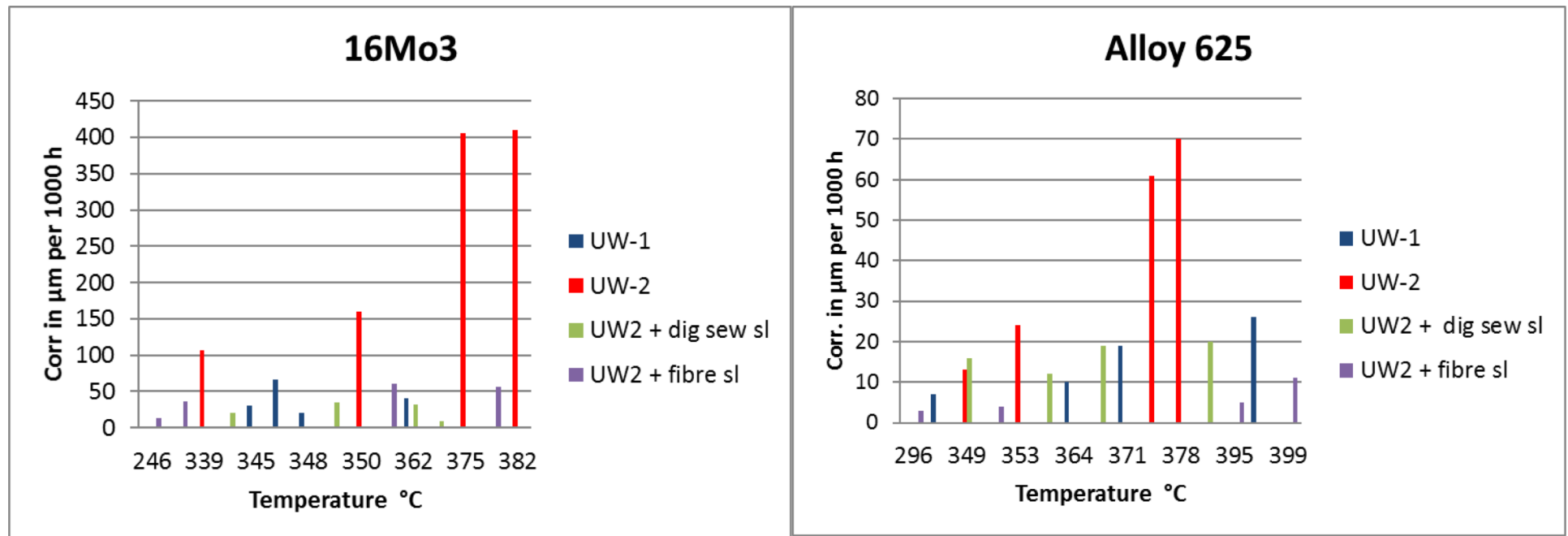
Fibre sludge

Sewage sludge delivered pre-mixed with some used wood



Results

Corrosion rate and temperature. 2 week tests ~330h. Av. temp for every test piece



16Mo3 - uncoated tube steel

UW-2 is very corrosive and corrosion rate increases rapidly with temperature.

UW-1 and UW-2 plus sludge show lower corrosion rates

Alloy 625 - Ni-base alloy coating material – note scale 0-80µm

UW-2 is more corrosive esp. at higher temps (above 370°C)

UW-1 and UW-2 plus sludge show lower corrosion rates.

Results – cross section analyses

Furnace wall corrosion-probes

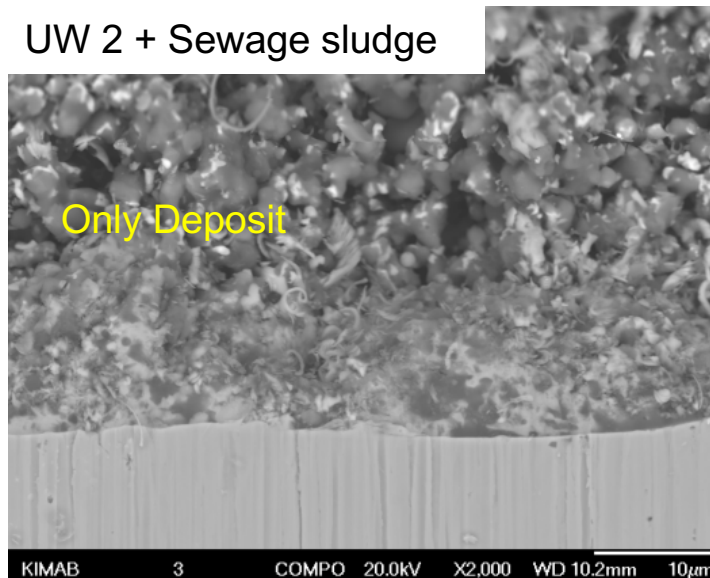
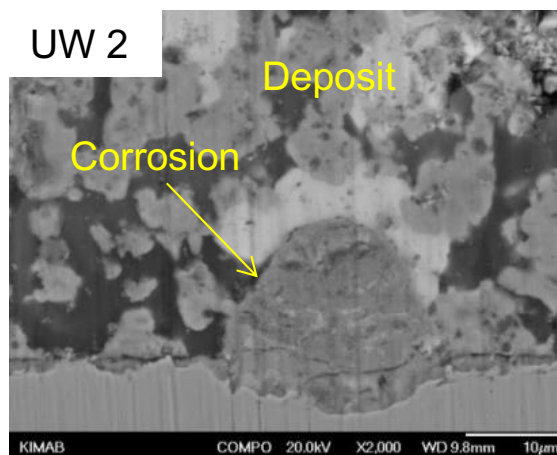
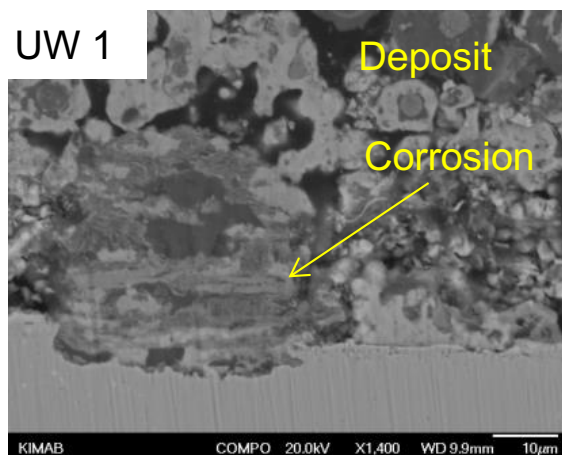
Alloy 625

350 °C

In general more corrosion for Alloy 625 sample with more aggressive fuel

Local corrosion with Ni, Cr- oxide as corrosion products

No/very little corrosion with sludge



Results – cross section analyses

Furnace wall corrosion-probes

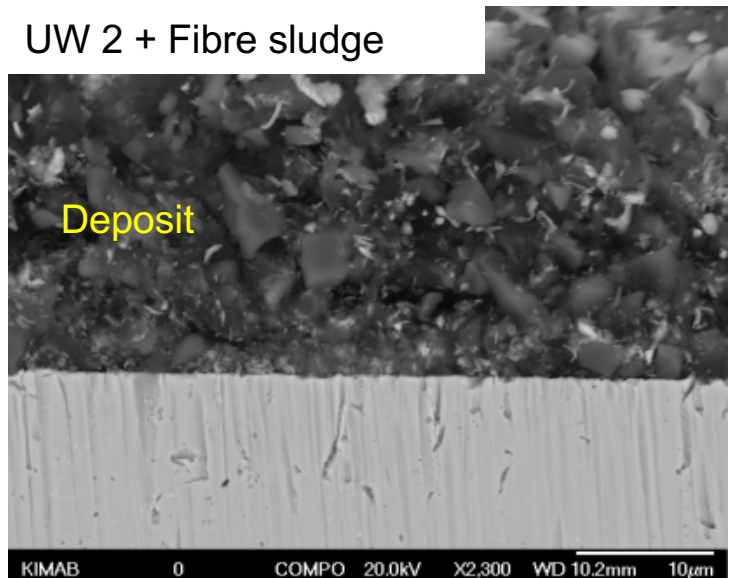
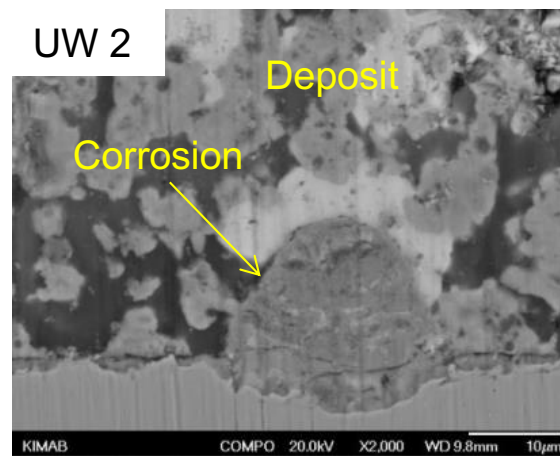
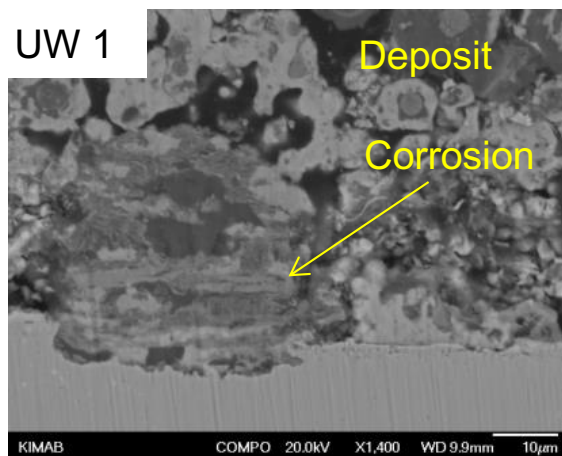
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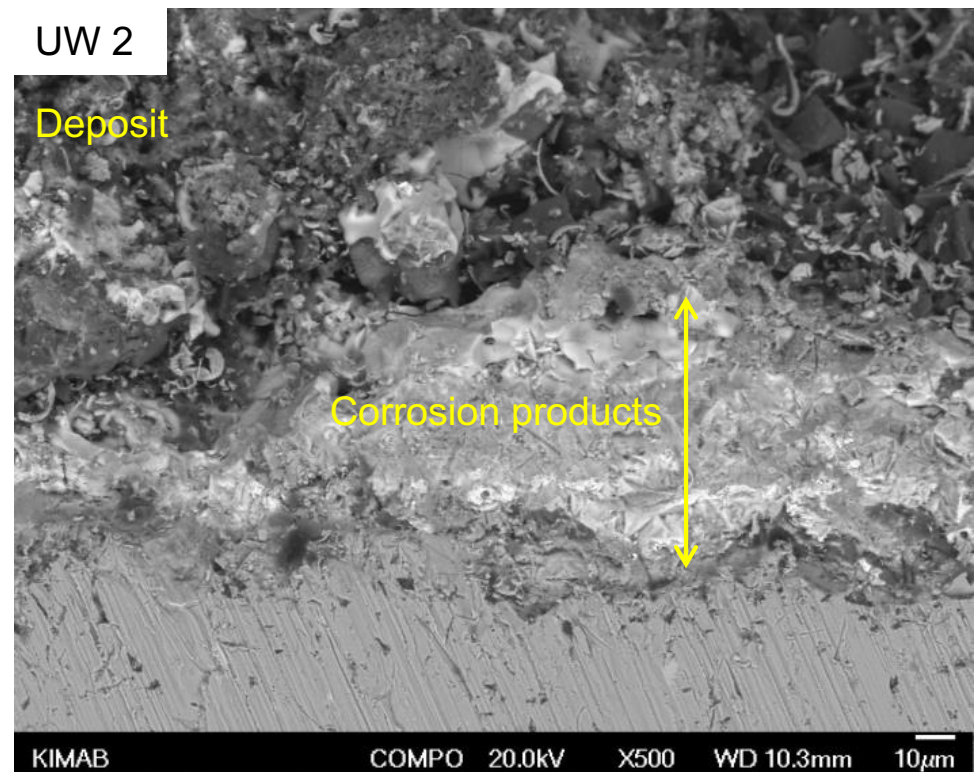
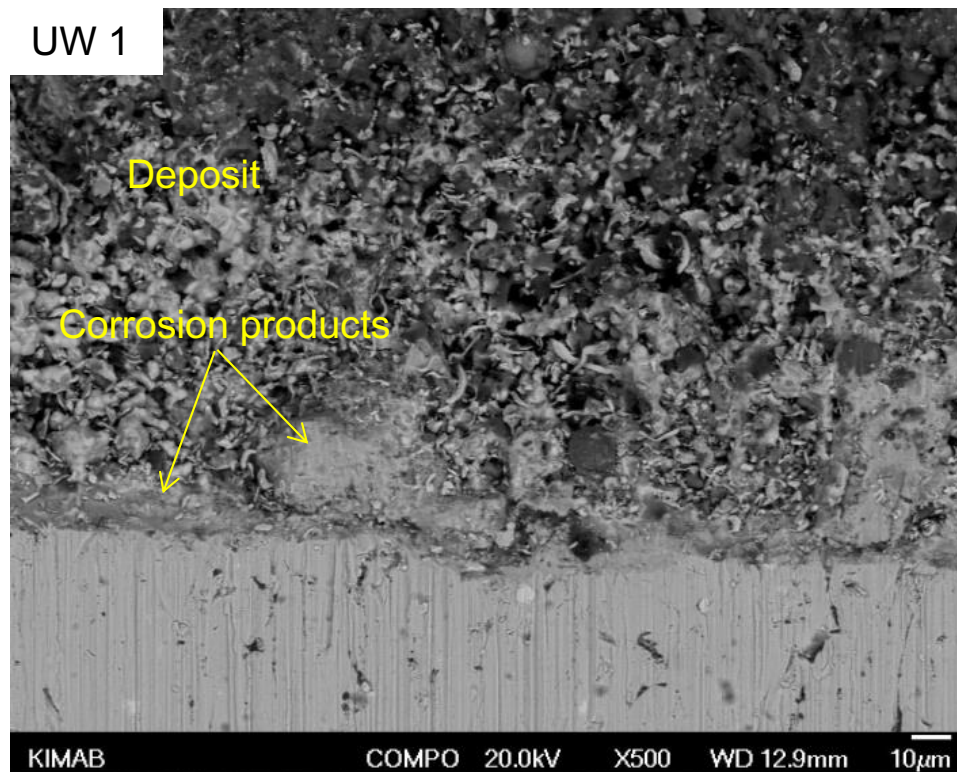
Results – cross section analyses

Furnace wall corrosion-probes

Alloy 625

400 °C

In general more corrosion with oxide formation for Alloy 625 sample with more aggressive fuel



Results – cross section analyses

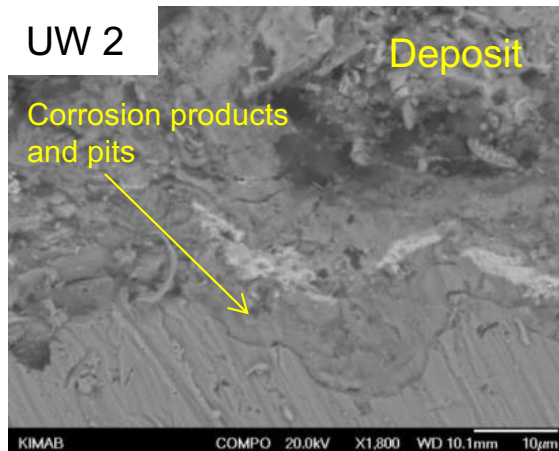
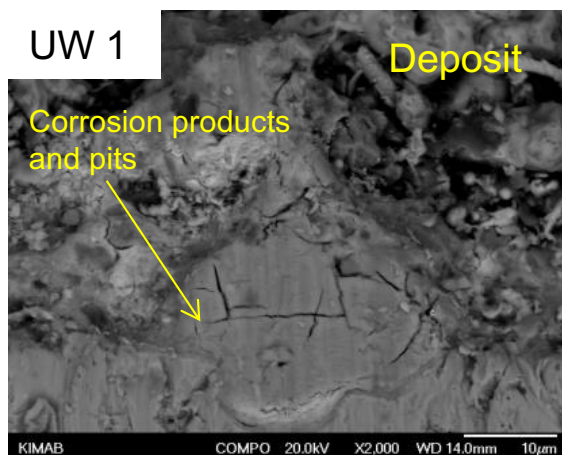
Furnace wall corrosion-probes

Alloy 625

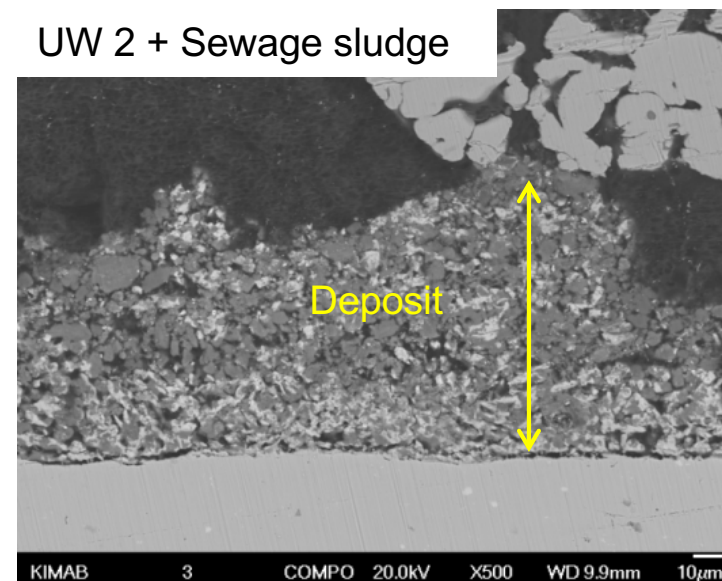
400 °C

Local corrosion with Ni, Cr- oxide and lead molybdate (UW2) as corrosion products

No/Very little corrosion



UW 2 + Sewage sludge



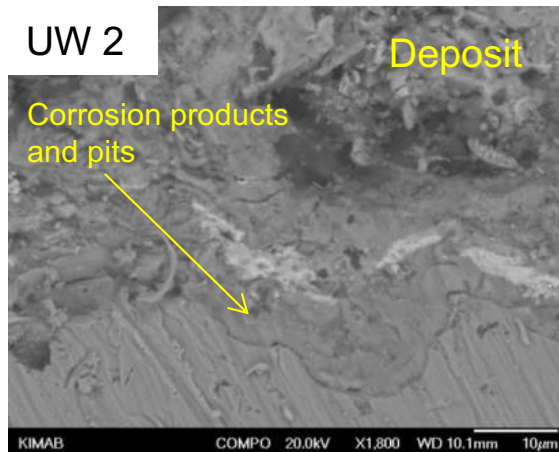
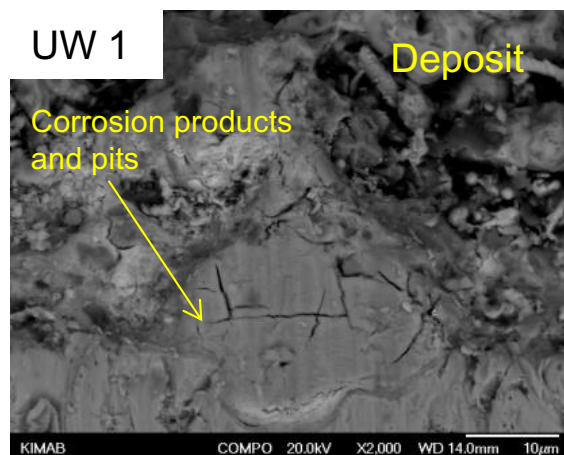
Results – cross section analyses

Furnace wall corrosion-probes

Alloy 625

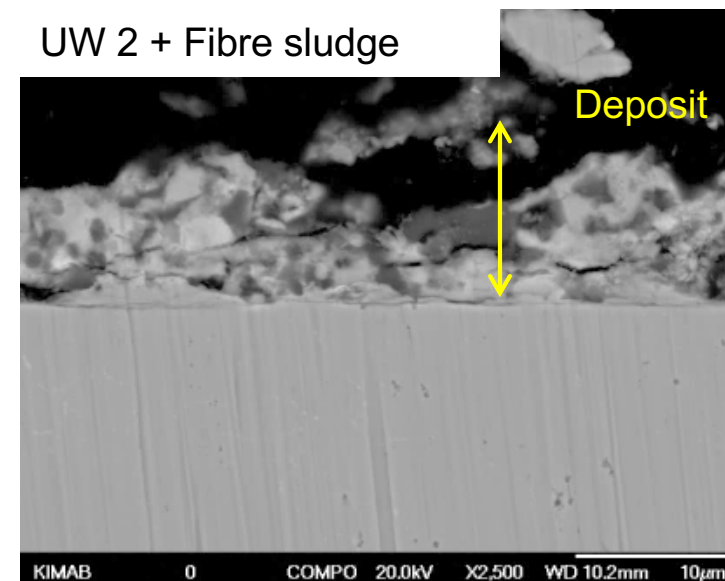
400 °C

Local corrosion with Ni, Cr- oxide and lead molybdate (UW2) as corrosion products



No/Very little corrosion

UW 2 + Fibre sludge

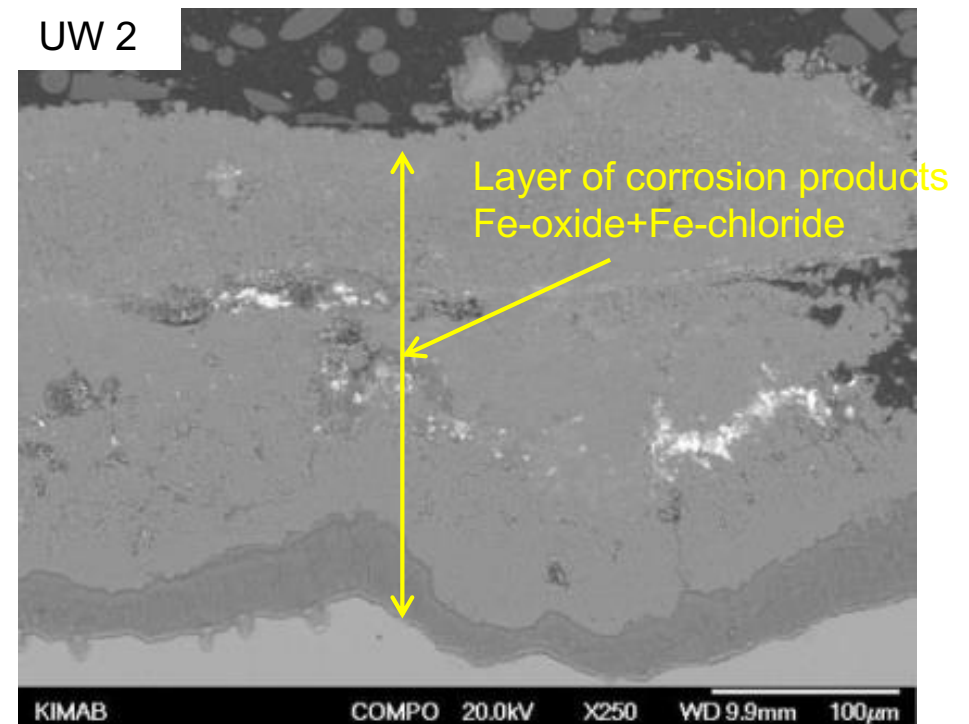
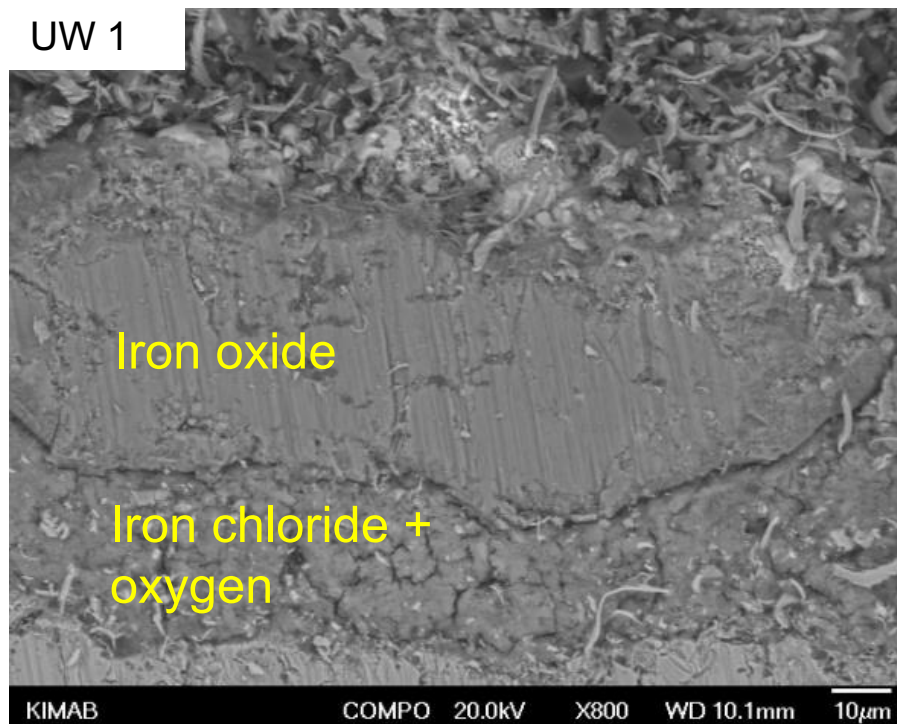


Results– cross section analyses

Furnace wall corrosion-probes

16Mo3 350 °C

Thicker layer of corrosion products for UW2



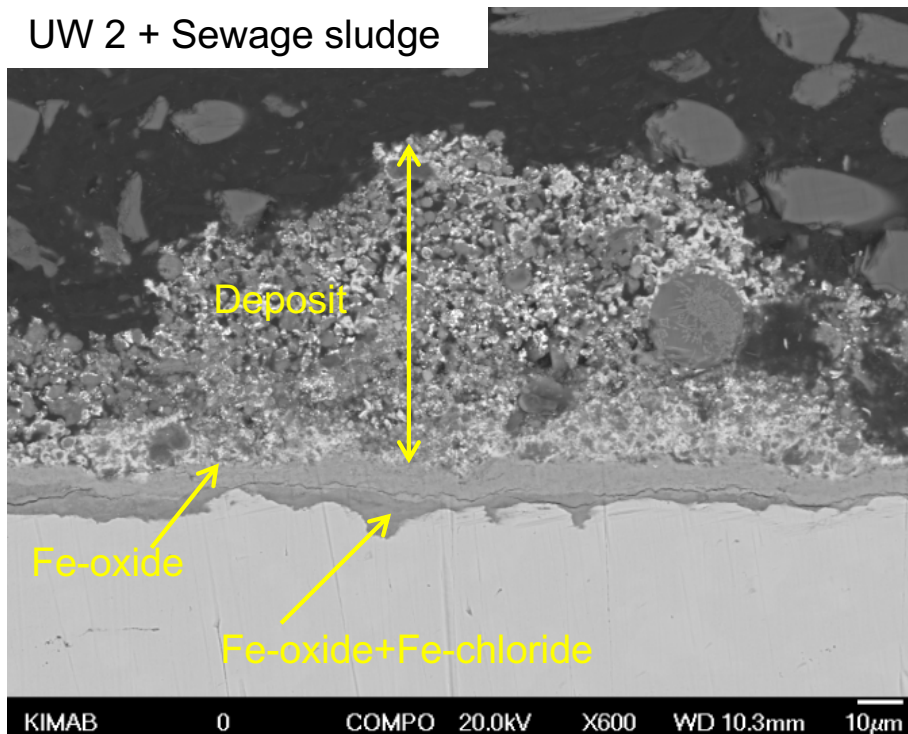
Results– cross section analyses

Furnace wall corrosion-probes

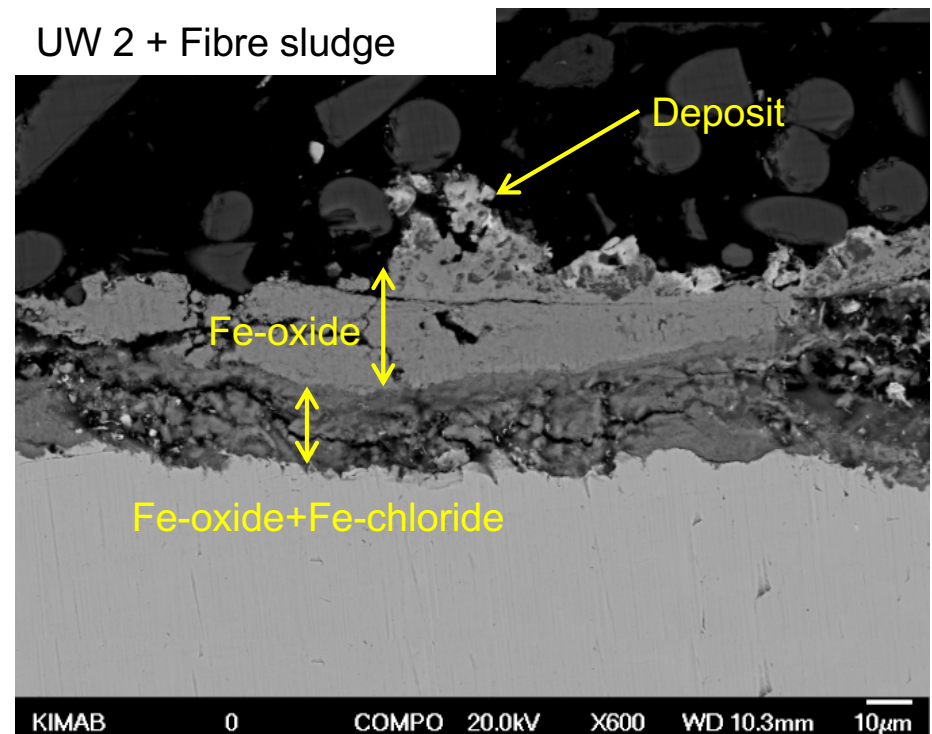
16Mo3 350 °C

Good results are observed when co-firing sludges

UW 2 + Sewage sludge

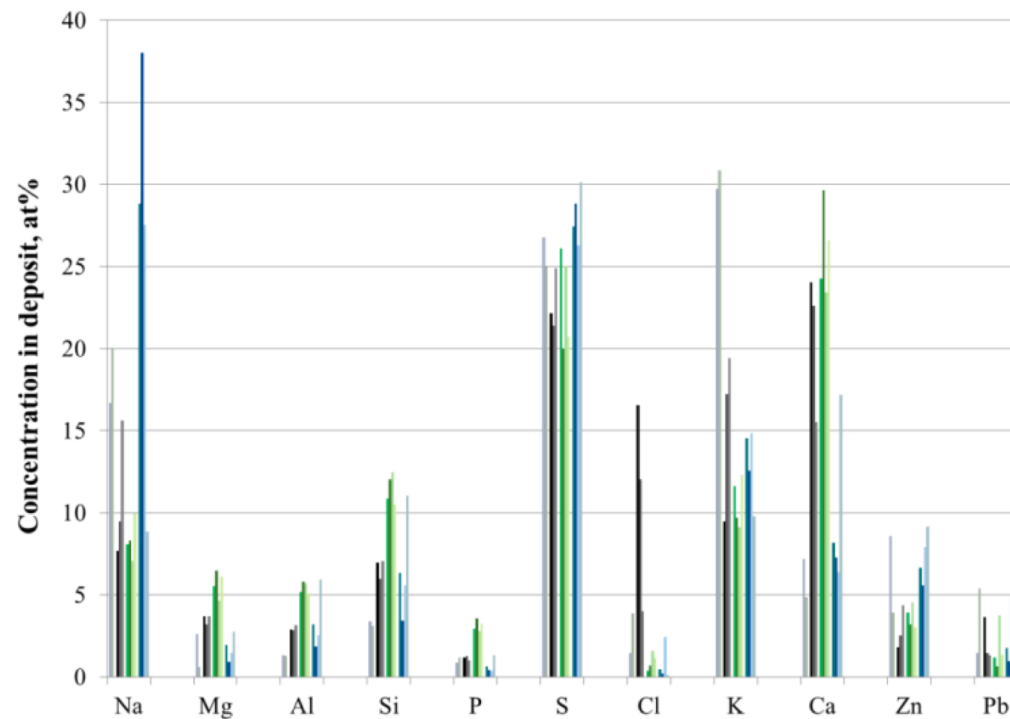


UW 2 + Fibre sludge



Results– deposit analyses

- Less alkali chlorides in deposits
- Instead higher amount of
 - CaSO_4 , Na/KSO_4 , Alkali-aluminasilicates
 - Found for both sludges but different amounts



	Sewage sl	Fibre sl
Samples [number]	1	1
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Si [mg/kg ds]	28 700	20 000
Cu [mg/kg ds]	259	17
Pb [mg/kg ds]	15	5
Zn [mg/kg ds]	524	170
P [mg/kg ds]	27 100	3 200

Conclusions – fuel quality & sludge campaigns

- Increasing the Cl and Pb-content in the fuel clearly also increase corrosion problems. (**KME708**)
- Co-firing of both sewage sludge and fibre sludge show reduced chlorine in deposit and decrease corrosion rates for tested materials at furnace wall position (336 h)
- Decreased corrosion and less Cl in deposits also at super heater position (deposit probes 3h)

RESULTS

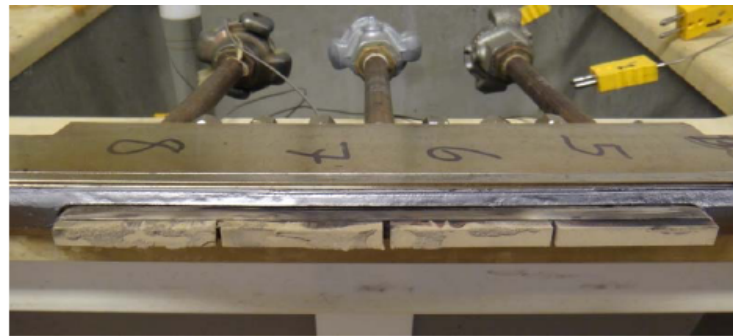
Coatings to decrease corrosion problems

Experimental - Idbäcken BFB

Test campaigns with coatings and overlay welds (~ 1000 h)

- Two probes, nominally 400°C at furnace wall.
- Used wood fuel
- 8 samples each test campaign
 - Sanicro [X], Alloy 625 solid, Alloy 625 welded, MH Engineering coatings, Kanthal APMT weld and solid, Model alloys (on-welded)

WALL CORROSION PROBE TESTING



Experimental – Blackburn Meadows

1-year test with coated tube (UW-fuel)

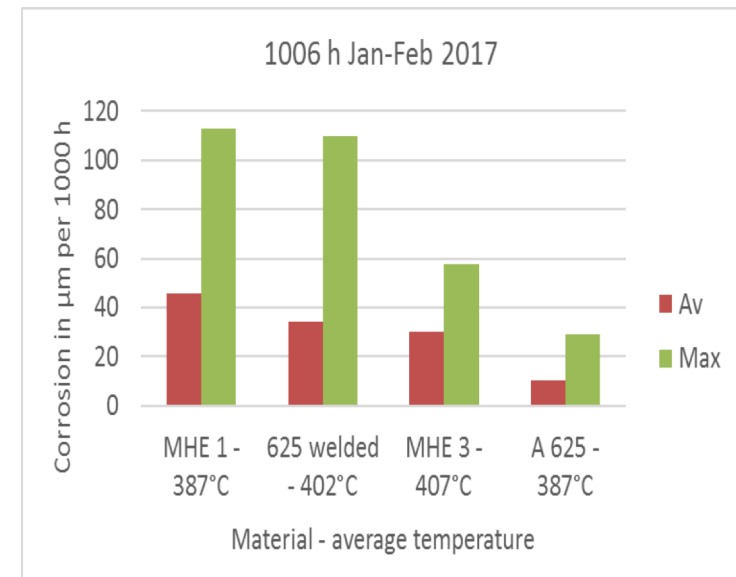
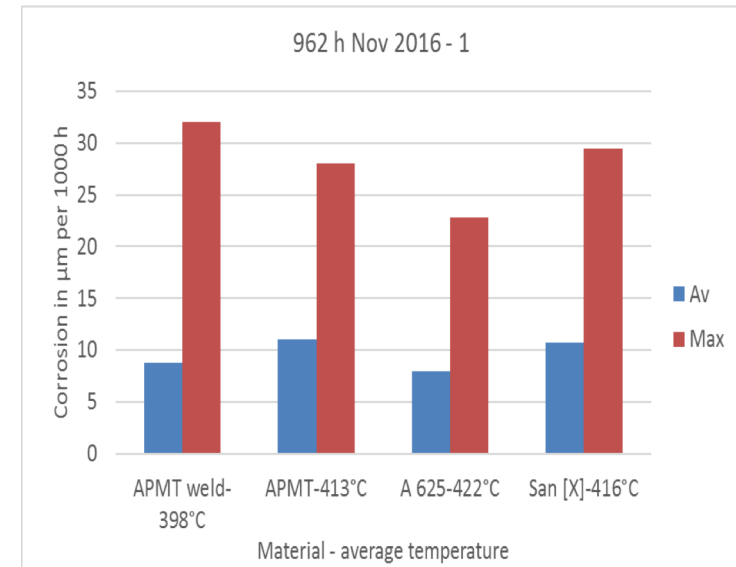
- Start July 2016, ended in June 2017 (~7000 operation hours)
- Multiple material combination, Part of a original tube cut out and replaced with this coated tube.

Materials	Application Method	Nominal Thickness
Sanicro60 (IN625)	Weld Overlay	4mm
Kanthal APMT	Weld Overlay	2mm
Sanicro60 (IN625)	Weld Overlay	4mm

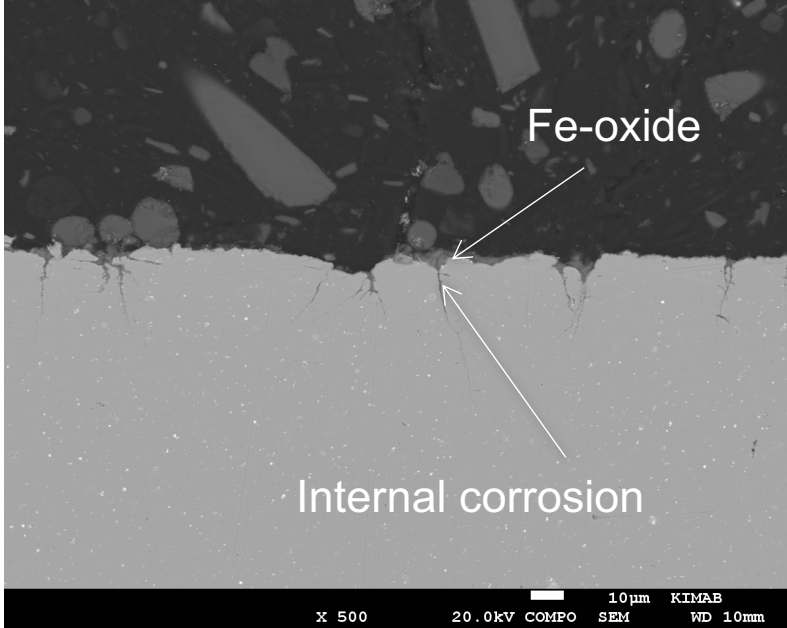
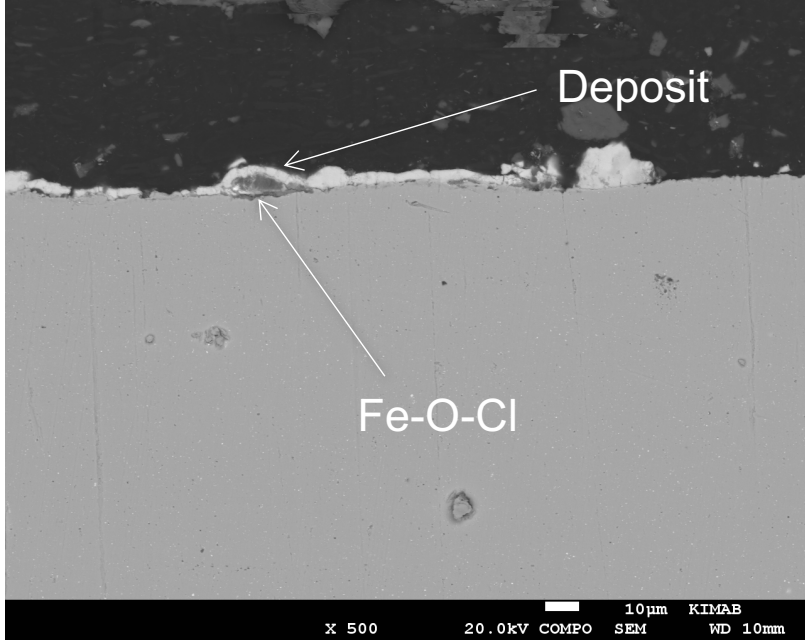


Results from Idbäcken

- Solid material (A625) performed better than welded.
- Welded A625, MHE1 and MHE3 showed similar results (20-45µm per 1000h)
- Solid San[X] similar to solid A625
- Welded FeCrAl model-alloys performed very well (less than 20µm per 1000h)

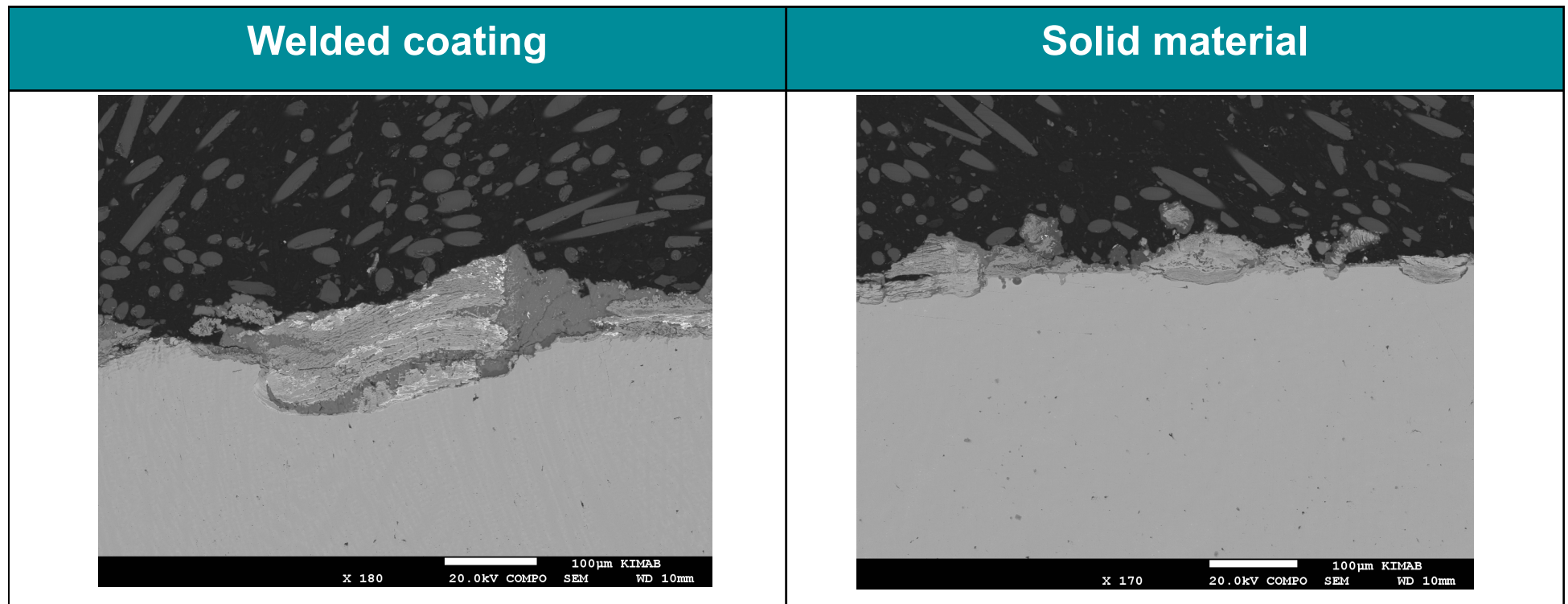


Results - APMT

Welded-coating	Solid material
 Fe-oxide Internal corrosion X 500 20.0kV COMPO SEM WD 10mm Oxide layer Internal corrosion (Cl)	 Deposit Fe-O-Cl X 500 20.0kV COMPO SEM WD 10mm Fe-O-Cl layer closest to substrate Deposit S, Cl, K, Pb No internal corrosion

- Maximum propagation of internal corrosion and Cl: 40µm

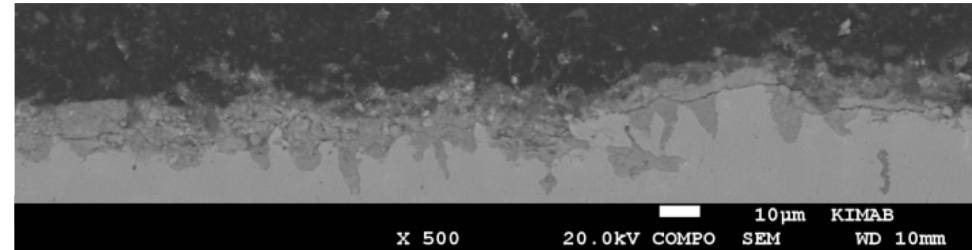
Results - Alloy 625



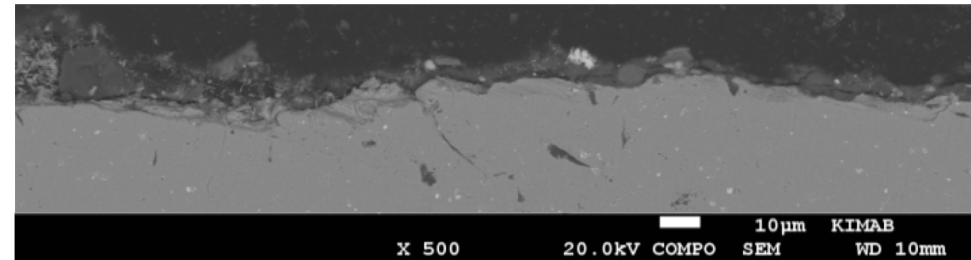
- Thickness uneven over sample
 - Average thickness for weld higher than solid material
- High amounts of Cl, K and Pb mixed in oxide/deposit

Results - Blackburn Meadows

- San60 10-20 μm thick corrosion layer but local. Some areas less.



- APMT not so much corrosion observed. Some internal corrosion but no thick oxide layer.



Similar behaviour of materials after 7000 h exposure time. No incidation of that internal corrosion for AMPT increases a lot with exposure time

→ FeCrAl-alloys promising to use as coating material

Goal fulfilments KME718

- Reduce operation and maintenance costs in boilers that burn predominantly used wood by the use of additives and coatings
 - The project has shown that by using additives and coatings, corrosion problems decrease. This is expected to lead to reduced operation and maintenance costs.
- Acquiring new and in-depth knowledge from longer term studies on the effect of using sewage sludge and one alternative sludge
 - The project has shown that two types of sludges can be used in order to decrease corrosion problems of materials typically used for furnace walls. Increased fuel flexibility!
- Investigating the corrosion properties of some new coating materials and their related performance with respect to furnace wall protection
 - The project has shown promising results for some coating materials to be used in order to decrease furnace wall corrosion.

Thank you for your attention!



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