

Corrosion of a Power Boiler Air Heater

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Overview

- Introduction
- Background
- Experimental procedure
- Analysis methodology
- General corrosion
- Localized attack
- Fuel composition
- Conclusions



thinned and perforated air heater tube

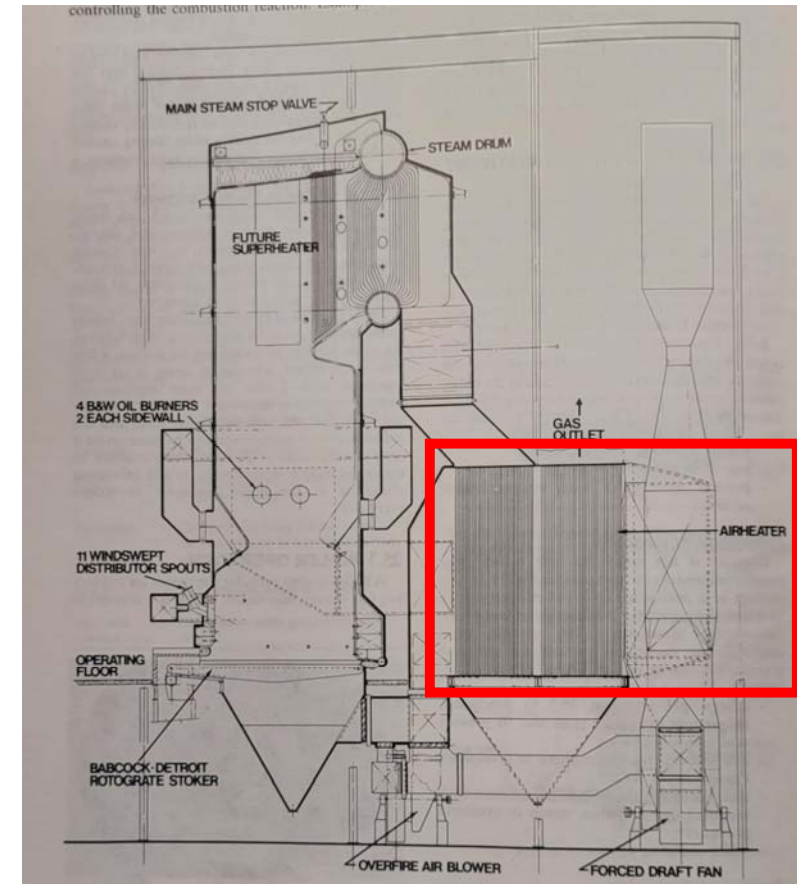


Introduction

Power boilers are designed to convert fuels to steam

Can process a range of fuel forms.

**Increasing boiler efficiency along with the need or desire to process the alternative fuel forms is a hot topic*

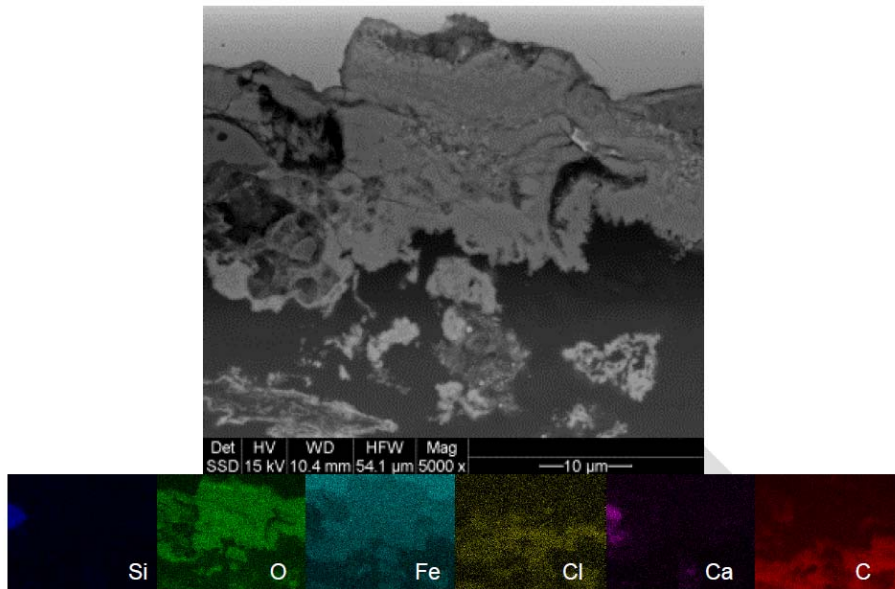


Smook, G. A., and M. J. Kocurek. 1982. *Handbook for Pulp & Paper Technologists*. Atlanta, GA, U.S.A. : Montreal, Quebec, Canada: TAPPI ; Canadian Pulp and Paper Association.

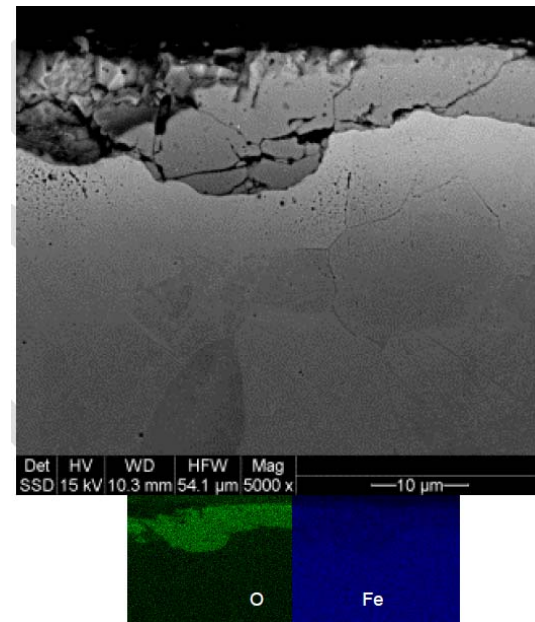


Background

Air heaters corrode on the flue gas side



Flue gas side scale on boiler tube is fragile, thick and porous



Scale on air side of boiler tubes is tenacious and protective



Background

Corrosion occurs when the tube temperature is below the dew point of the flue gas containing sulphur and/or chloride

	Temperature
Water	69.2 °C
Sulphuric Acid	118.5°C
Sulphurous Acid	67.4°C
Hydrochloric Acid	67.6°C

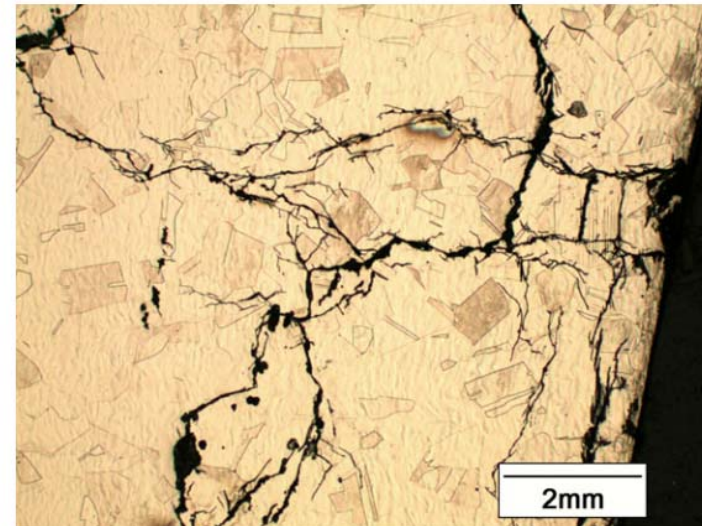
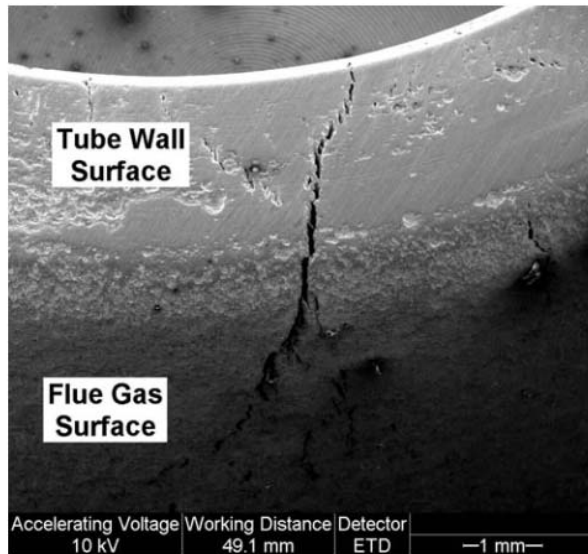
Traditionally, this corrosion is managed in two ways

1. Air heater temperature held above dew point
2. Improve alloy of boiler tubes



Background

300 grade austenitic stainless steels are not suitable for air heater environments due to stress corrosion cracking



304L tubes in a flue gas environment of a coastal biomass boiler at 65 °C for a period of 13 weeks

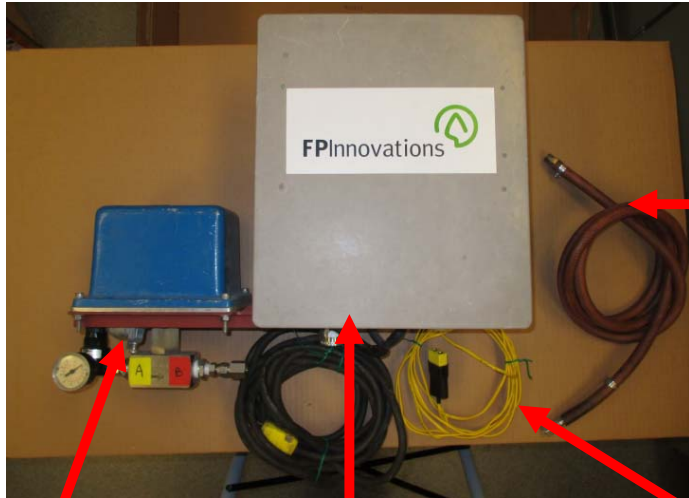


Alloys

Element	CS A1018	304L	2205	2507	F255	254SMO	COR-TEN	S-TEN
	G10180	UNS S30400/ S30403	UNS S32205	UNS S32750	UNS S32550	UNS S31254	-	-
C	0.18	0.023	0.023	0.021	0.013	0.01	0.12	0.04
Cr	0.101	18.36	22.54	25.30	25.33	20.50	0.55	--
Ni	--	8.1	4.89	7.05	5.75	18.10	0.26	0.17
Mo	--	0.32	3.08	3.84	3.34	6.10	0.01	0.04
N	--	0.082	0.17	0.253	0.243	0.21	--	--
Cu	0.24	--	--	0.27	1.66	0.64	0.31	0.27
Mn	0.82	1.43	1.76	0.79	0.96	0.53	--	0.105
P	0.01	0.032	0.024	0.42	0.023	0.02	--	0.015
S	0.024	0.024	0.008	0.001	<0.0003	0.0016	--	0.012
Si	0.21	0.24	0.48	0.42	0.27	0.31	--	0.17
Fe	BAL	BAL	BAL	BAL	BAL	BAL	BAL	BAL
CTE (10 ⁻⁶ K ⁻¹)	13	17.2	13.5	14	12	16.5	11.8	--



Field Setup



Mill
supplied air

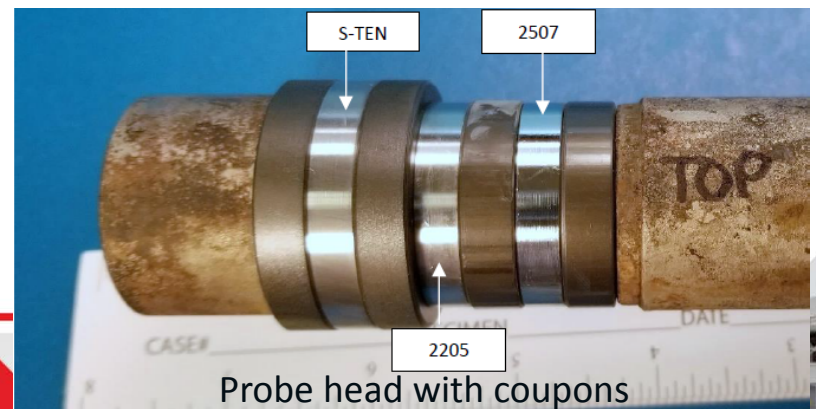
Proportional
control air
valve

Temperature
control box
(65°C)

Thermocouples
connected to
metal samples



Air heater probe fitted with coupons



Probe head with coupons

Trial Matrix

^[1] There is no distinct data for fuel characteristics for probes 5 and 6 during time of exposure. Both probes were exposed in the same boiler, and the mill personnel only shared averages values for the fuel used during the trials.

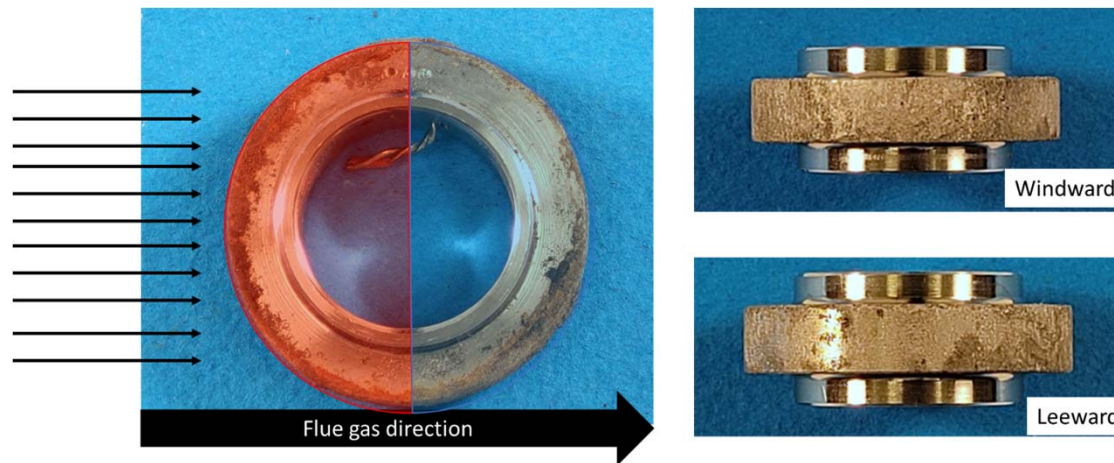
Probe	Mill	Exposure Duration (days)	Alloys evaluated	Fuel	Chlorine content (ppm)	Sulfur content (ppm)	Sulfur to chlorine molar ratio	Moisture content (%)
1	A	22	A1018, 2205, 2507	Hog fuel + CDW + BS	466.7	663	1.6	44.4
2	A	14	A1018, 2205, 2507	Hog fuel + CDW	458.3	100	0.2	45.1
3	A	14	A1018, 2205, 2507	Hog fuel + BS	537.5	300	0.6	43.3
4	B	259	COR-TEN, 304L, 2205, 2507	Hog fuel + BS	60	1158	21.3	55.4
5	C	174	254SMO, F255, 2205, 2507, COR-TEN	Salt laden hog fuel + BS	2619	1060	0.4	57.7
6	C	204	2205, 2507, S-TEN	Salt laden hog fuel + BS	2619	1060	0.4	57.7

CDW= construction demolition waste; BS = Bio-sludge



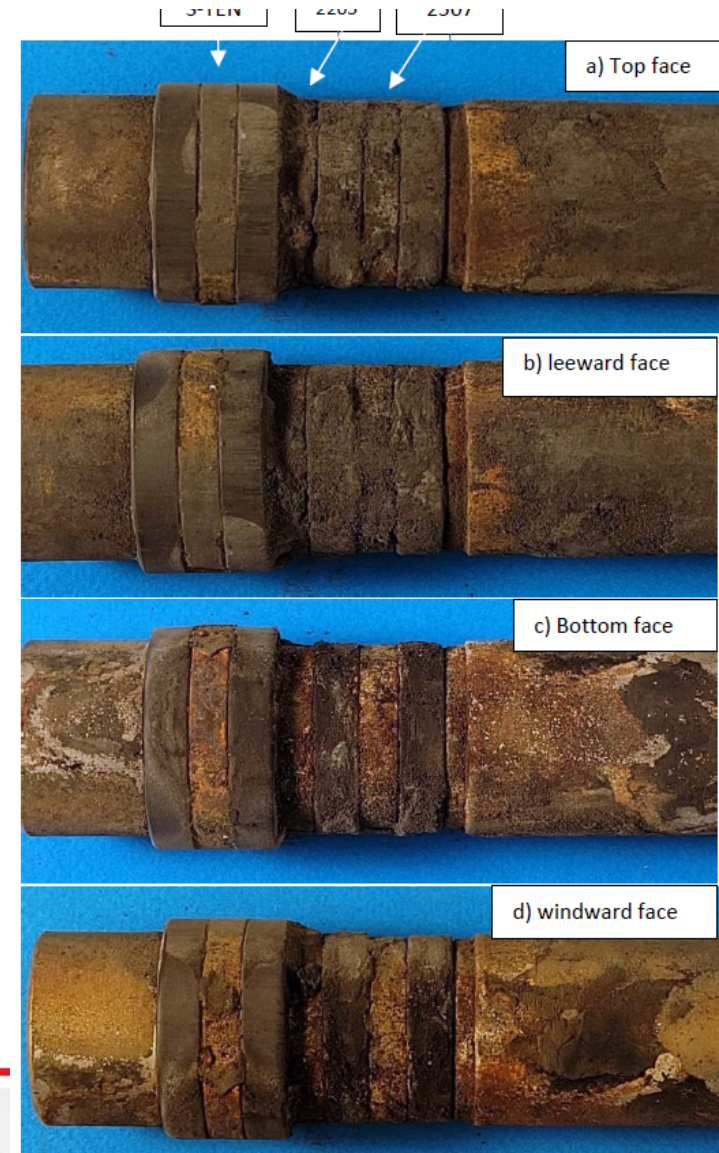
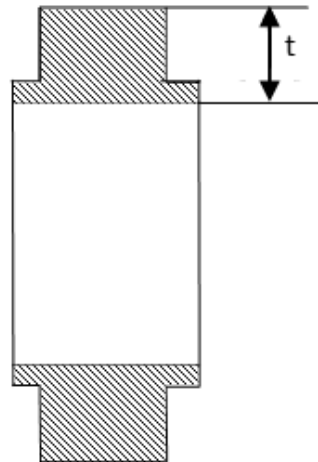
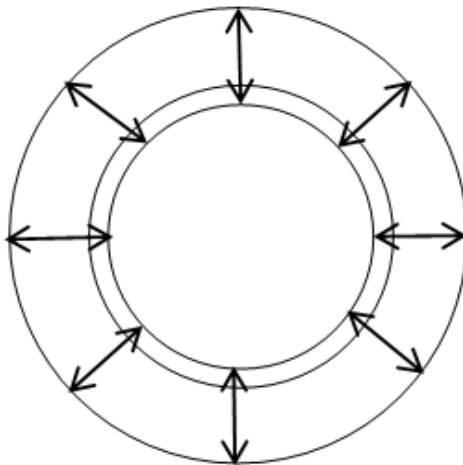
Analysis method

Standard weight loss approach is not suitable in air heater environments for corrosion since the relevant damage mechanism is localized corrosion. Additionally, corrosion is not symmetrical.



Analysis

Thickness measurements taken in 8 locations per sample



Results

Average metal loss (um/d)

	A1018	304L	2205	2507	F255	254SMO	COR-TEN	S-TEN
noon	-4.87	-0.08	-0.50	-0.60	-0.34	-0.23	-1.52	-0.82
1:30	-5.82	-0.12	-0.66	-0.44	-0.40	-0.63	-1.41	-0.77
3:00	-5.56	-0.08	-0.57	-0.32	-0.52	-1.87	-1.47	-0.59
4:30	-7.64	-0.08	-0.53	-0.64	-0.37	-0.57	-1.48	-0.47
6:00	-7.66	-0.12	-0.87	-0.71	-2.44	-0.26	-1.87	-0.34
7:30	-7.71	-0.12	-0.92	-0.72	-1.52	-0.06	-2.01	-0.26
9:00	-8.05	-0.15	-1.09	-0.52	-0.37	-0.36	-1.97	-0.39
10:30	-6.67	0.00	-0.86	-0.72	-0.43	-0.63	-1.43	-0.57
AVG	-6.75	-0.09	-0.75	-0.58	-0.80	-0.58	-1.65	-0.53
Corrosion Mechanism	General	Pitting and SCC	Pitting	Pitting	Pitting	Pitting	General	Pitting



Results

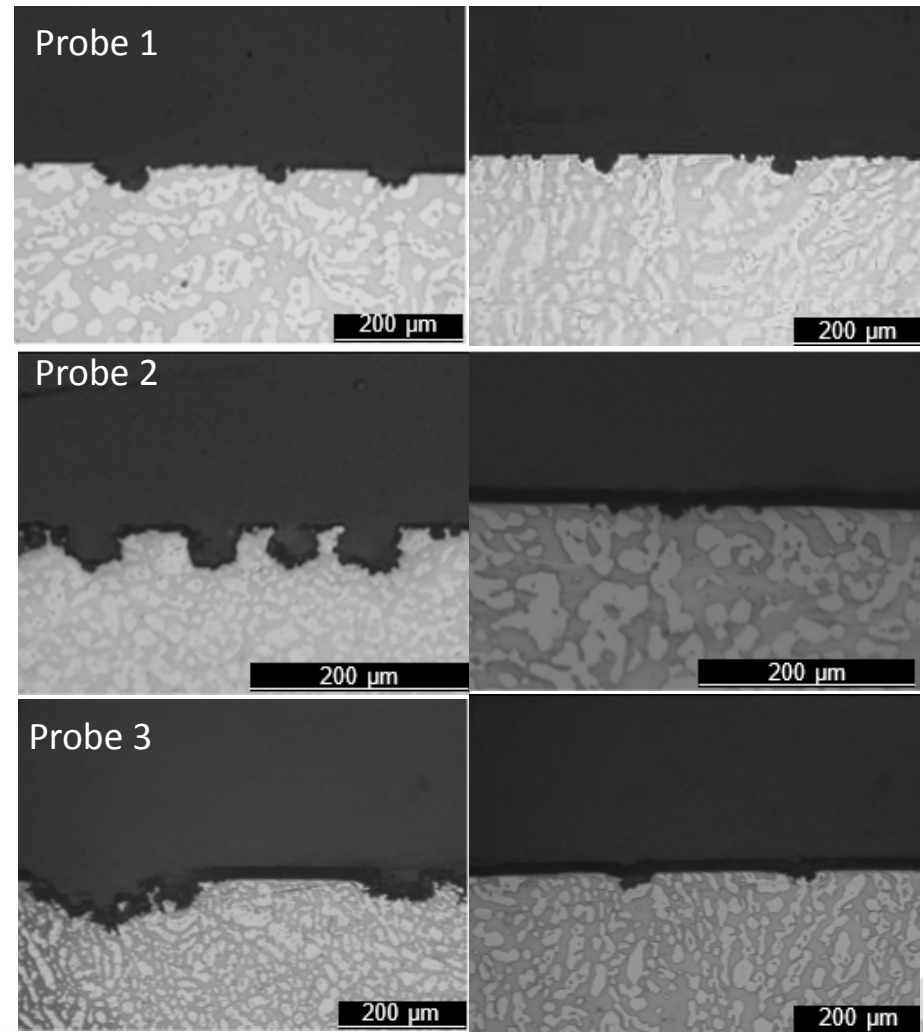
Average metal loss

By probe	A1018	304L	2205	2507	F255	254SMO	COR-TEN	S-TEN
Probe 1	-4.26	-	-0.74	-0.84	-	-	-	-
Probe 2	-9.55	-	-1.96	-0.98	-	-	-	-
Probe 3	-6.43	-	-0.45	-0.63	-	-	-	-
Probe 4	-	-0.09	-0.05	-0.02	-	-	-0.30	-
Probe 5	-	-	-0.80	-0.71	-0.80	-0.58	-2.99	-
Probe 6	-	-	-0.51	-0.32	-	-	-	-0.53



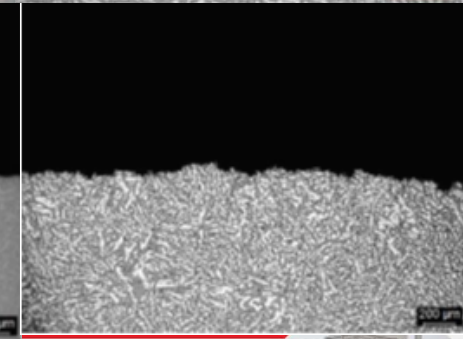
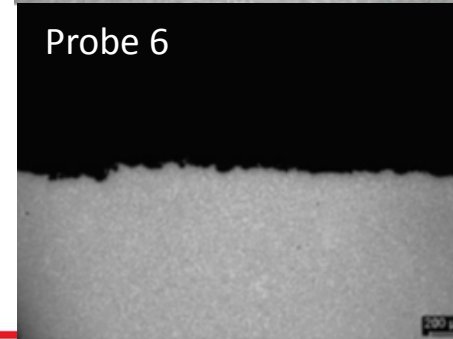
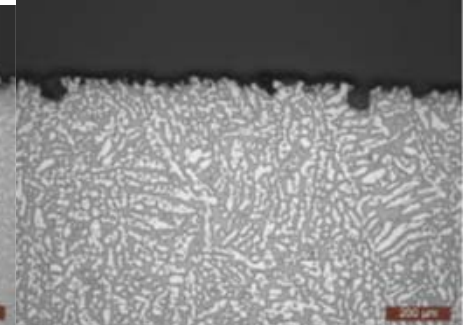
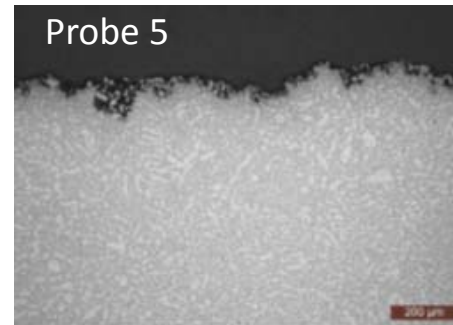
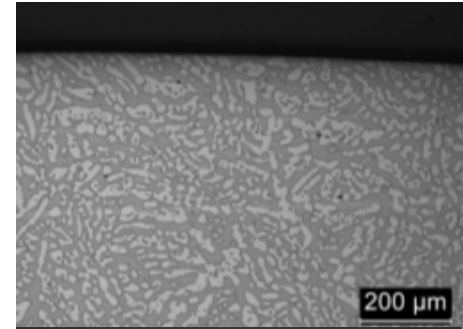
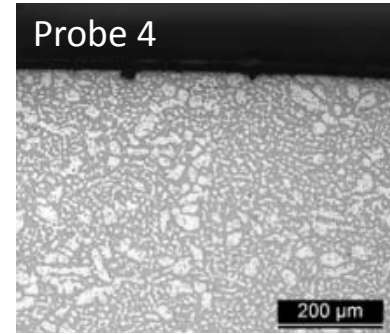
Microscopy

2507 vs 2205 from different probes and environments



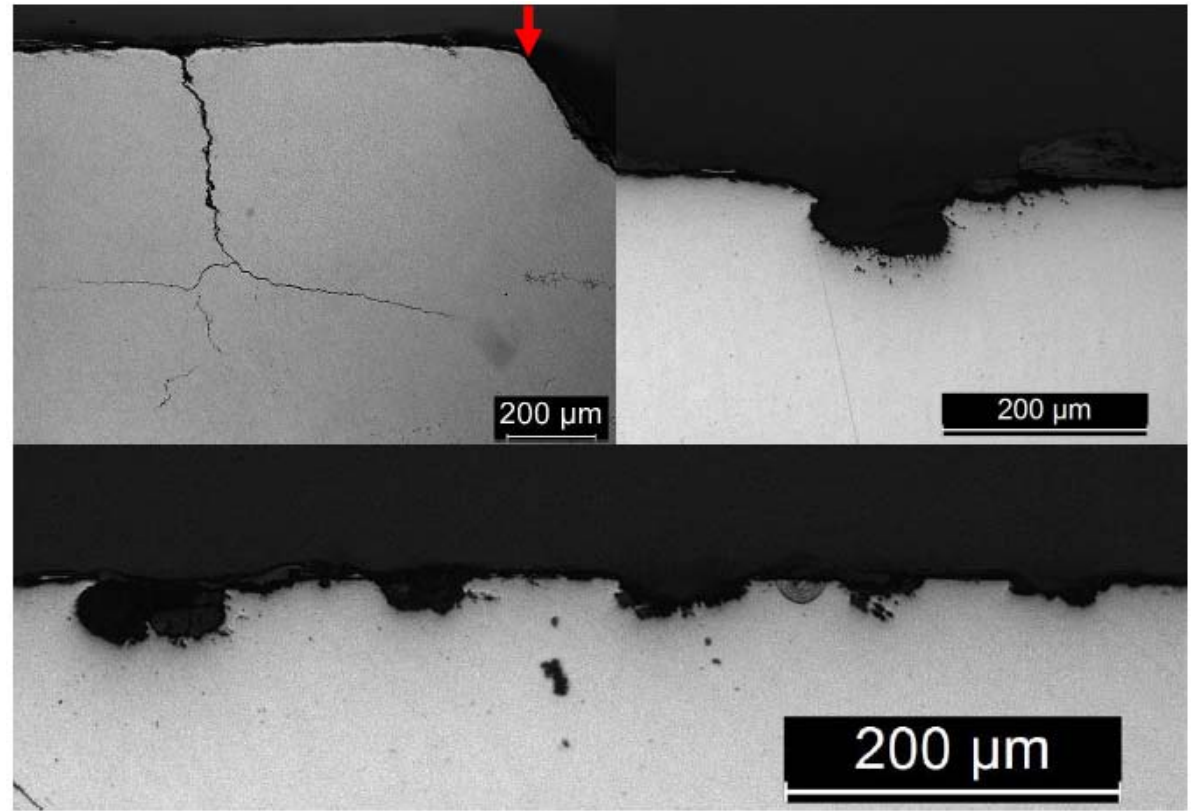
Microscopy

2507 vs 2205 from different probes and environments



Microscopy

Probe 4 (Hog fuel + BS)
demonstrate the
susceptibility of 300 grade
austenitic steel to stress
corrosion cracking and
localized attack



Results

Increased sulphur concentration in fuel may increase attack, but it is more likely the ratio between sulfur in chloride

Literature suggest:

- Sulfur decreases the presence of alkali chlorides by sulfation which do not attack passive films and a ratio less than 2 is corrosive, above 4 is non-corrosive*

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Conclusions

- Acid dewpoint corrosion is the primary attack mechanism.
- Austenitic stainless steel, 304L, is susceptible to stress corrosion cracking.
- 254SMO > 2507 > 2205 ~ F255 > S-TEN > 304L > COR-TEN > 1018 carbon steel.
- The corrosiveness of the fuels was assessed by measuring the metal loss. This showed **low S/Cl ratios** are more conducive to corrosion.
- Solutions:
 - Steam-coiled heat exchangers to pre-heating inlet combustion air above the water dewpoint
 - Proper alloy selection: a more corrosion resistant alloy will provide energy saving by reducing the need to pre-heat the inlet combustion air and assist an overall increase in boiler efficiency.

