Impacts of Fuel Quality on Power Production

29 October – 3 November Snowbird, Utah, USA

Corrosion and Deposit Investigations During Large Scale Co-combustion of Switchgrass at a Coal-fired Power Plant

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Outline of presentation

- Introduction to the Chariton Valley biomass project
- Co-firing history at Ottumwa Generation Station
- Present co-firing test program at Ottumwa
- Deposition investigation
- Corrosion studies
- Conclusion

Chariton Valley Biomass Project

Partners

- A cooperative effort between the Chariton Valley Resource Conservation and Development Inc., Alliant Energy, Prairie Lands Biomass LCC and the US Department of Energy

Aim

- To grow 200,000 ton/year switch grass (SWG) as an alternative revenue generating crop
- To improve soil stability and reduce soil erosion
- Replace 5% of the coals used at Alliant Energy's Ottumwa Generation Station by Co-firing of switch grass

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SWG co-firing history at Ottumwa

- First co-firing test conducted Nov. 2000 through Jan. 2001:
  - -Objective: to observe impacts of co-firing
  - -Co-firing of 15.2 t/h SWG possible without adverse impacts
- Second co-firing test Nov. - Dec. 2003:
  - -Improved SWG processing equipment
  - -Verify results from first campaign
  - -Characterization of ash samples
- Objectives of the present campaign (Feb. - May 2006):
  - -Assess long term impacts on boiler operation
  - -Emphasize on corrosion and deposition phenomena

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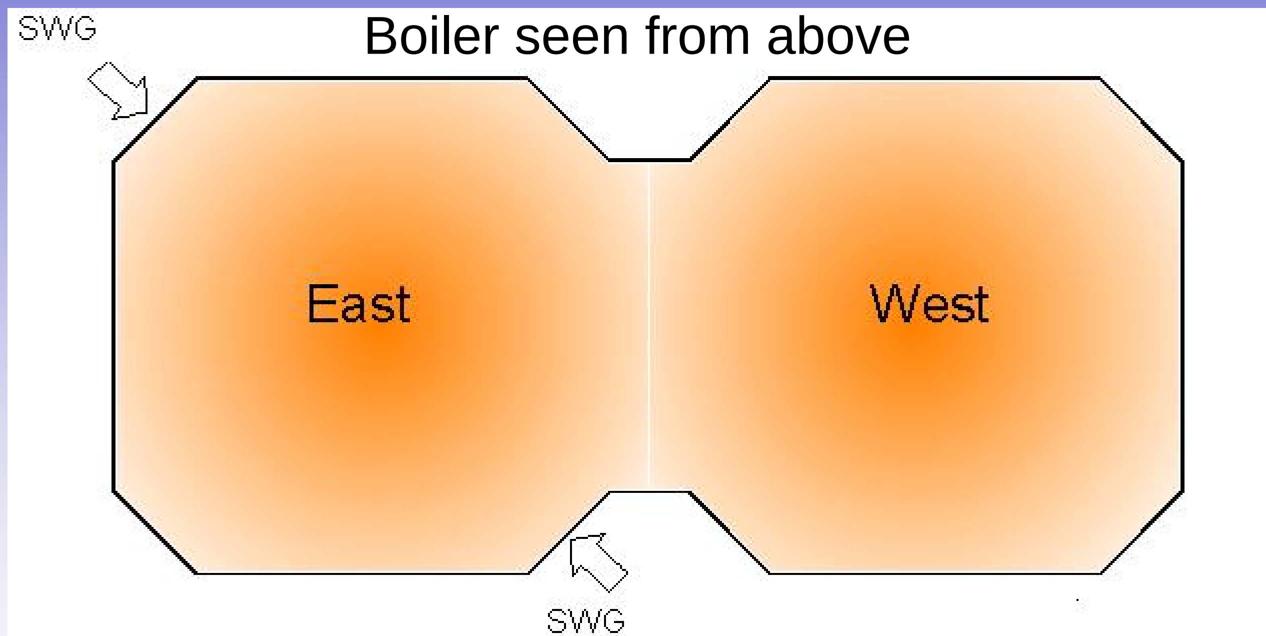
Ottumwa Generation Station

- Located in Iowa, USA
- Operated by Alliant Energy
- 725 MW_e PF unit with ESP
- Corner-fired, twin furnace design
- PRB low sulfur coal

Co-firing concept at Ottumwa

- Current capacity of SWG processing system is 12.5 t/h (≈2.5% at full load)
- Cut SWG is added to two opposing burners



Summary of present test program

Corrosion test tubes:

- Installed before co-firing campaign (Feb. - May 2006)
- 2800 hours exposure, only SWG co-firing during last 1675 hours

Deposit tests:

Test #	*Date*	*Time*	*Boiler load*	*SWG share (%-wt., dry)*
Co-firing				
1	22. March	9^{00} - 14^{00}	100%	3,1
2	22-23. March	23^{00} - 04^{00}	50%	5,1
3	23. March	9^{00} - 14^{00}	100%	3,0
4	23-24. March	23^{00} - 04^{00}	50%	4,6
5	24-25. March	7^{00} - 09^{00}	“normal load”	3,3
Coal reference				
1	3 July	8^{00} - 12^{00}	100%	-
2	3 July	12^{00} - 16^{00}	100%	-
3	5 July	20^{00} - 00^{00}	50%	-
4	6 July	00^{00} - 4^{00}	50%	-
5	6-7 July	6^{00} - 6^{00}	“normal load”	-

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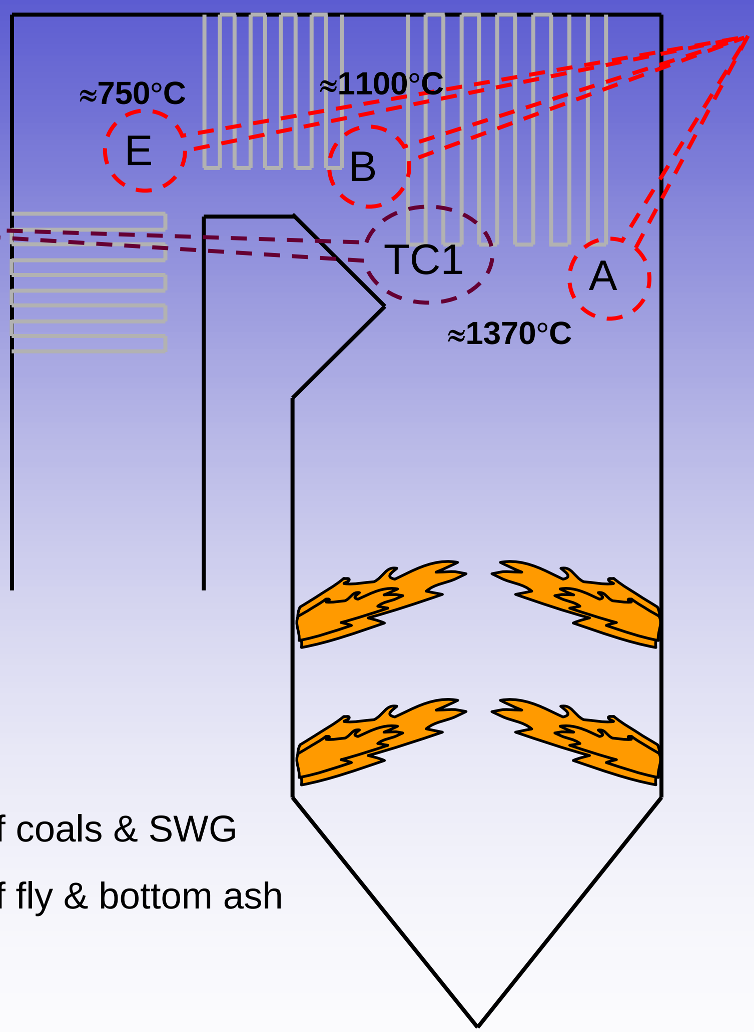
Boiler measurements



Deposit probes

- 540^{o}C surface temperature
- Material: 10CrMo910 steel
- Exposure time: 3-24 hours
- Deposit samples analyzed:

  -Elemental analysis

  -Soluble(aq) K, Na, S & Cl

- SEM analysis of test rings

Test tubes

- 540^{o}C metal temperature
- Exposed for 2880 hours
- 4 types of steel tested
- Mounted in epoxy and analyzed by SEM-EDX

Fuel & ash

- Sampling and analysis of coals & SWG
- Sampling and analysis of fly & bottom ash

Fuel characteristics

	Moisture (%-wt.,a.r.)	*Ash (%-wt.,dry)*	*LHV (MJ/kg, dry)*
Coal (reference - July)	22.6	6.4	27.6
Coal (co-firing - March)	26.0	6.1	27.6
SWG	7.7	5.9	18.3

	Si	Al	Ti	Fe	Ca	Mg	Na	K	P	S	Cl
Coal (reference - July)	0.97	0.47	0.05	0.26	1.18	0.22	0.09	0.02	0.02	0.30	0.002
Coal (co-firing - March)	0.88	0.55	0.05	0.21	1.10	0.20	0.11	0.02	0.02	0.29	0.002
SWG	1.79	0.07	0.00	0.05	0.51	0.14	0.01	0.39	0.12	0.07	0.07

Changes in bulk ash composition

Test	*SWG share (%-wt., dry)*	*Gain in K+Na (%)*	*Al/(K+Na)*	*Si/(K+Na)*	*Cl/(K+Na)*	*2S/(K+Na)*
Pure coal (average)	0	-	3.9	6.0	0.01	3.6
Co-firing (50% load)	4.8	13	3.3	5.7	0.03	3.2

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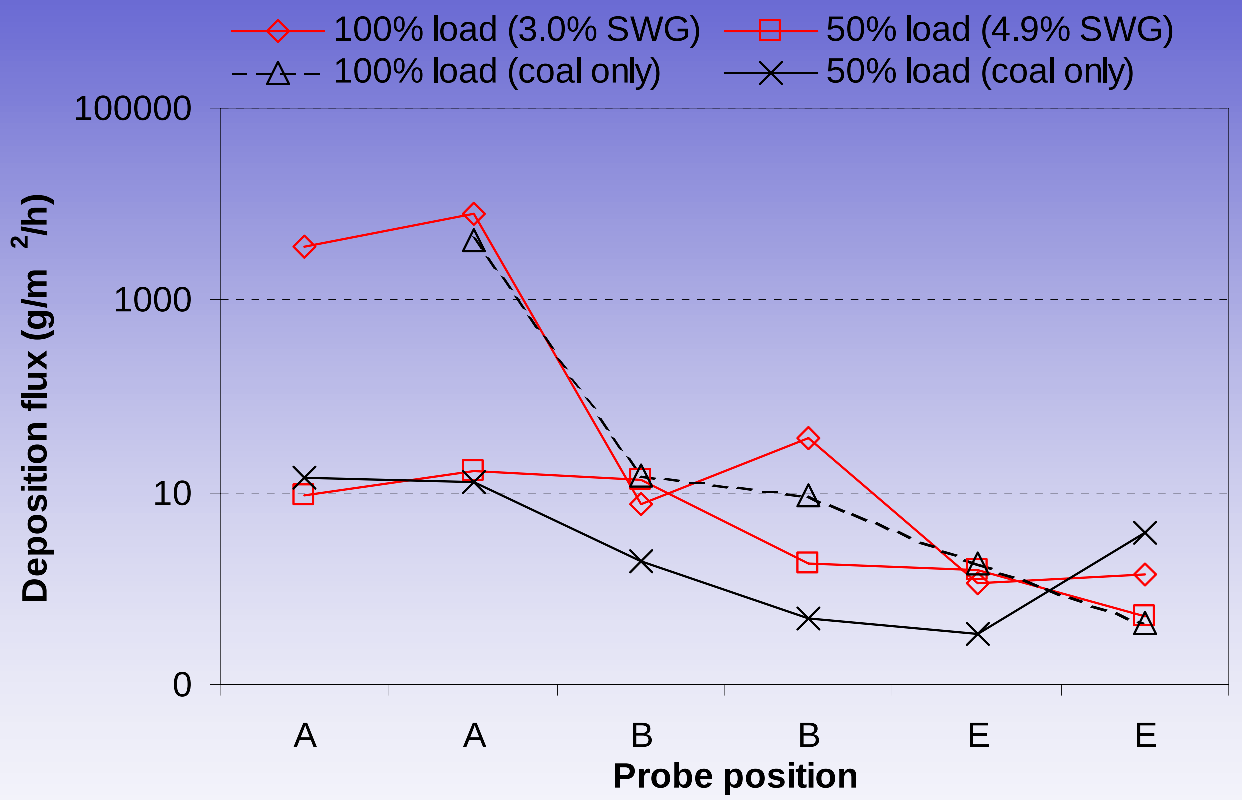
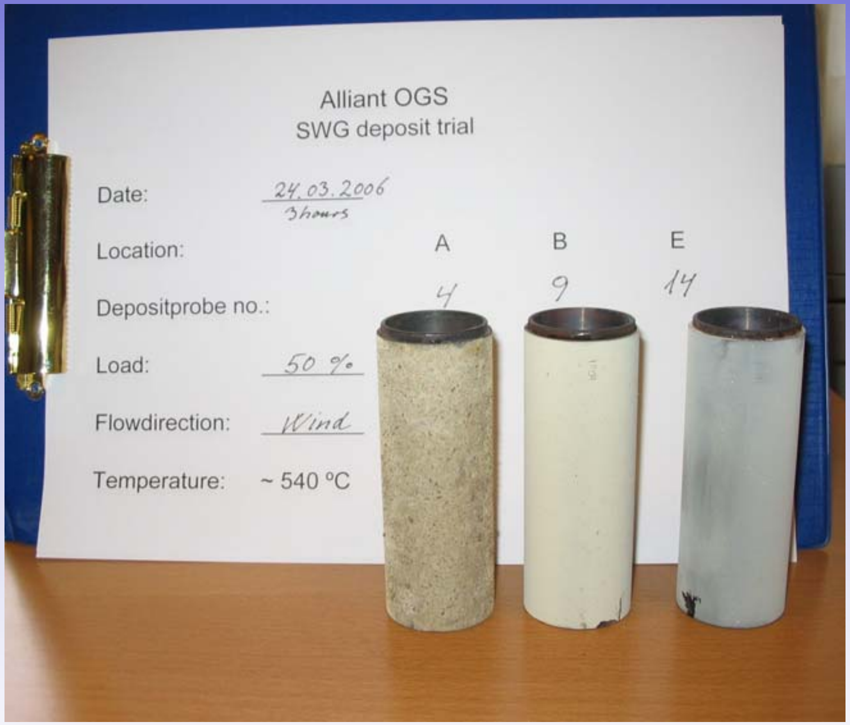
Results – Deposition fluxes



Results – Deposit samples

SWG co-firing 100% load

SWG co-firing 50% load



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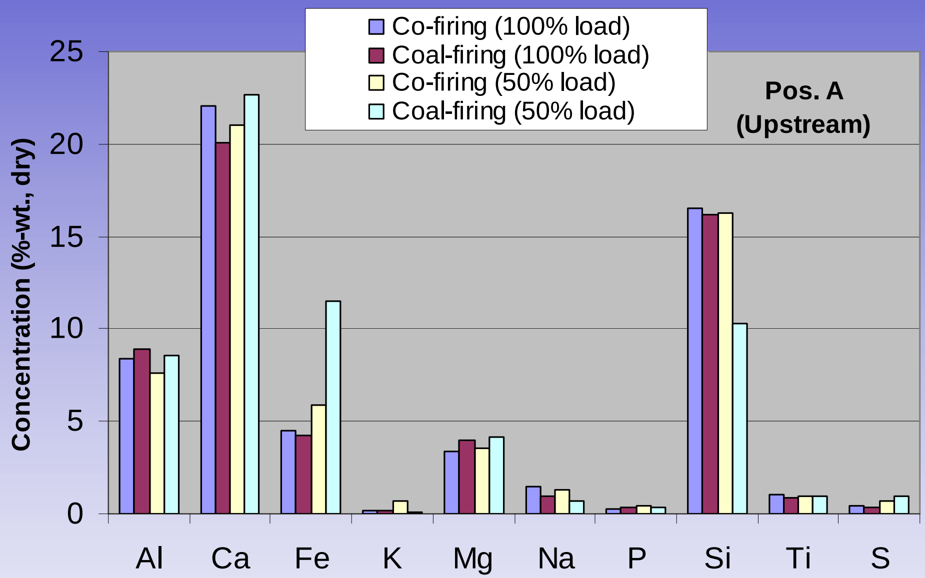
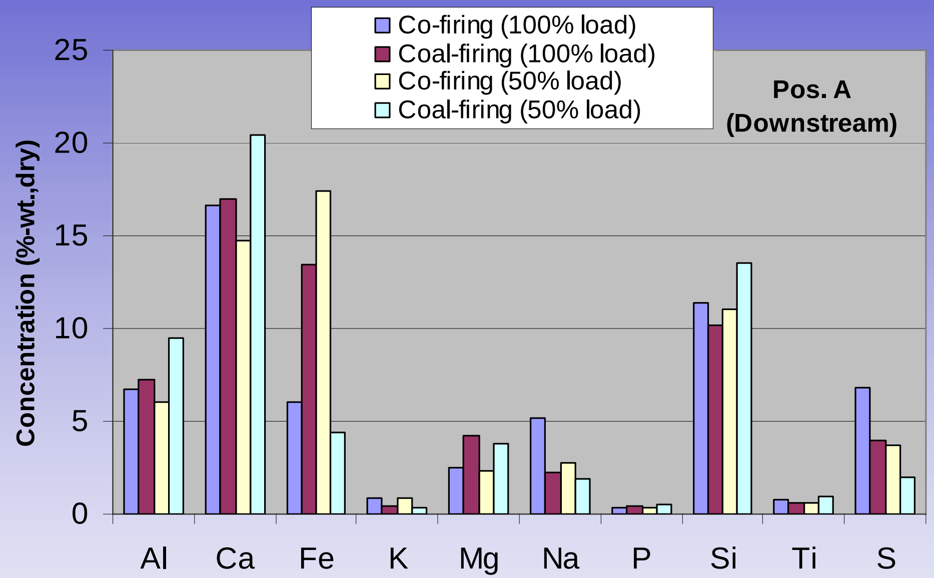
Deposits – Composition pos. A

All deposit samples were collected over 3 hours

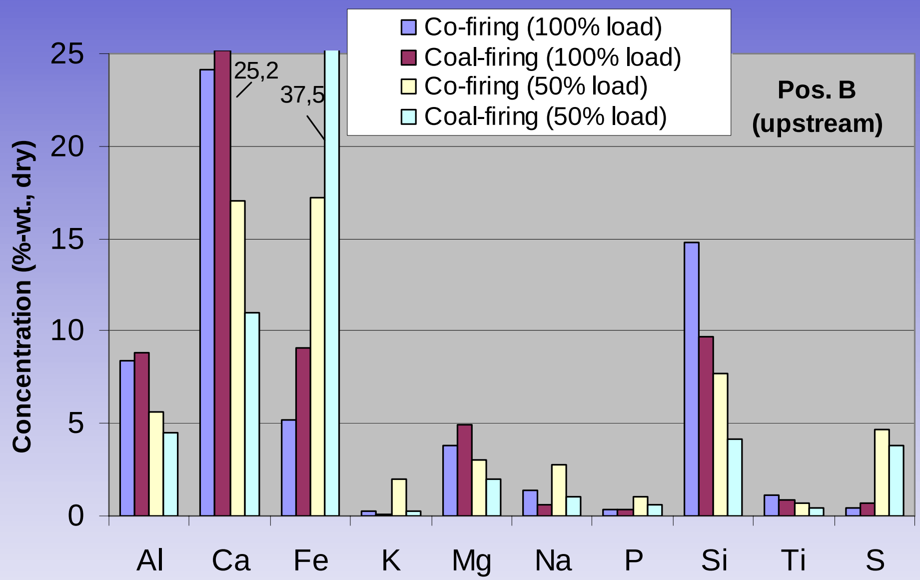


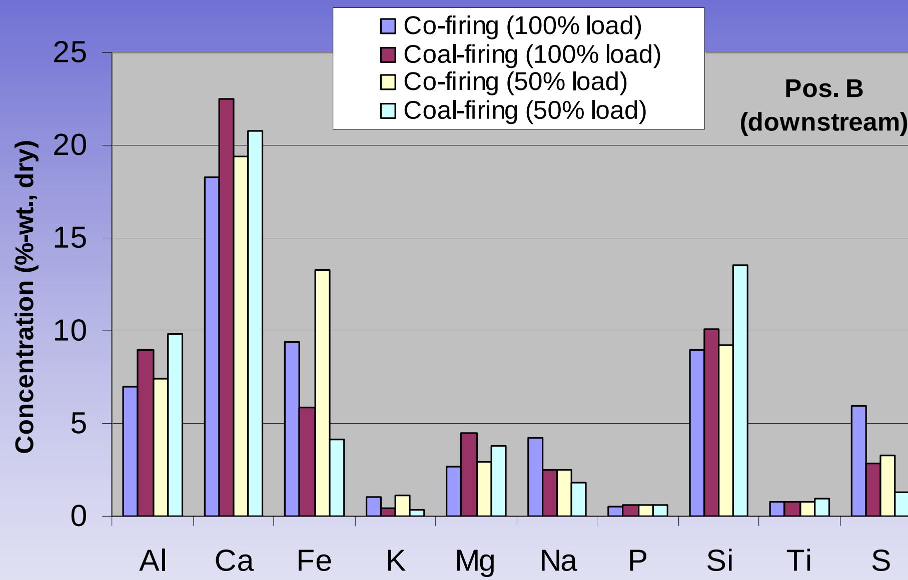


- Cl <0.1 %-wt. for all samples (typically below DL)

Deposits – Composition pos. B

All deposit samples were collected over 3 hours





- Cl <0.1 %-wt. for all samples (typically below DL)
- High Fe content due to steel contamination!

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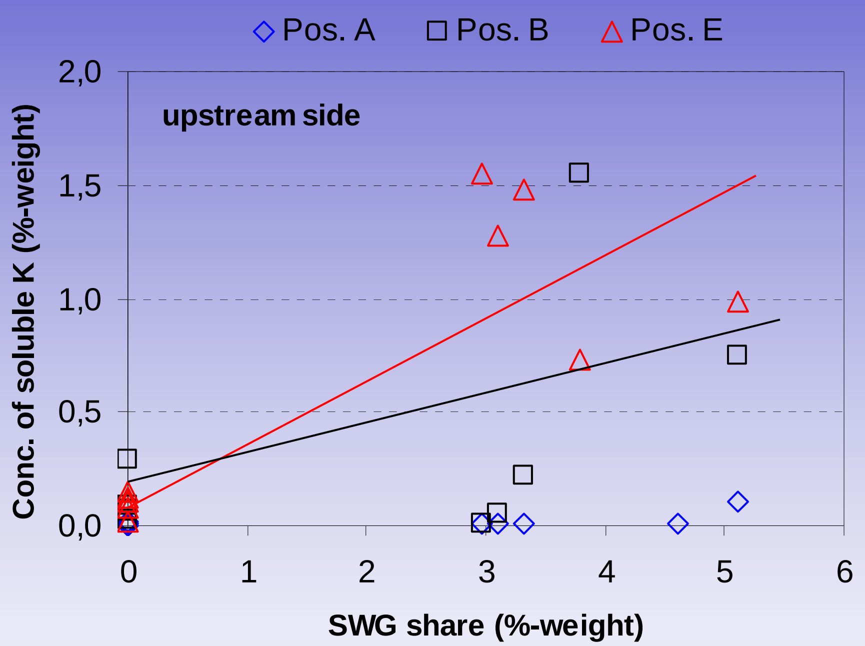
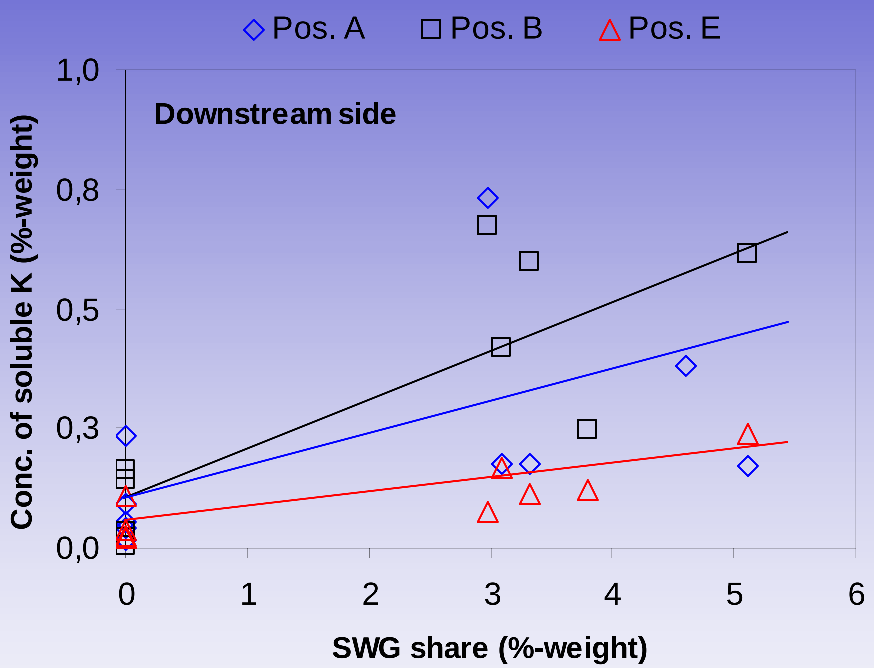
Deposits – Water-soluble K





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Fly ash composition

Comparison of SWG co-firing and coal fly ash

Test	*Na(aq)*	*K(aq)*	*Si*	*Al*	*Fe*	*Ca*	*Mg*	*Na*	*K*	*S*	*Cl*
SWG Co-firing:											
Test 1 – 100% load	0.97	0.09	15.4	8.7	4.3	20.5	3.6	3.0	0.44	1.37	0.002
Test 2 – 50% load	0.93	0.12	15.2	8.4	4.0	21.2	3.6	2.9	0.44	1.43	0.002
Coal reference:											
Tests 1,2 – 100% load	0.35	0.04	15.8	8.9	3.7	19.7	3.9	1.9	0.32	0.86	0.001
Test 3 – 50% load	0.30	0.03	15.6	9.1	3.6	20.0	3.8	1.8	0.30	0.90	0.001

- Small increase in potassium and soluble potassium during co-firing SWG
- However small variations in coal composition (e.g. Na) have greater impact

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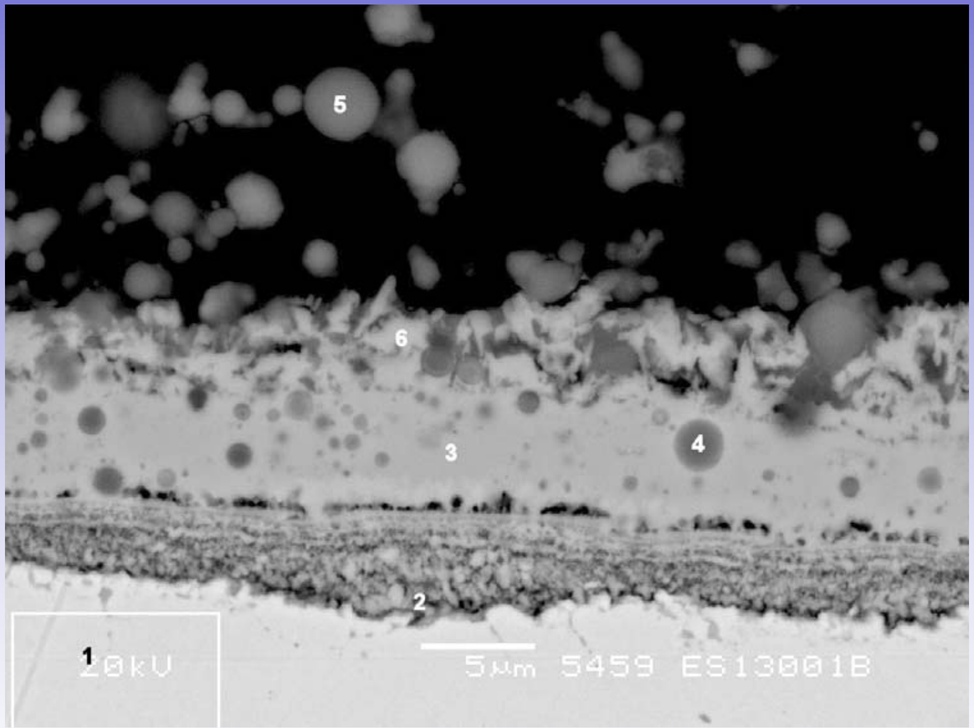
Corrosion studies – Deposit test rings

SEM image of test ring (pos. A) after 3 hours at 540°C, co-firing Test #4



SEM-EDX results

- No Cl or K present within deposit or oxide layer
- Al, Ca & Si rich particles
- Na & S present between particles

Corrosion studies – Test tubes

- Test tubes installed for 2880 hours (1675 with SWG co-firing)
- Metal temperature 540ºC
- Flue gas temperature at full load ≈1350ºC
- Test specimens were cross-sectioned and mounted in epoxy
- Four different steel materials were tested

Material	*C*	*Fe*	*Cr*	*Ni*	*Mn*	*Mo*	*Nb*	*Si*
10CrMo910	0.07-0.15	rest	2.0-2.5		0.40-0.70	0.90-1.0		0.20-0.50
13CrMo44	0.08-0.18	rest	0.70-1.10		0.40-1.00	0.40-0.60		0.10-0.35
347H	0.04-0.10	rest	17.0-20.0	9.0-13.0	<2.0		0.8-1.0	<1.00
304H	0.04-0.01	rest	18.0-20.0	8.0-10.5	2.00			0.75

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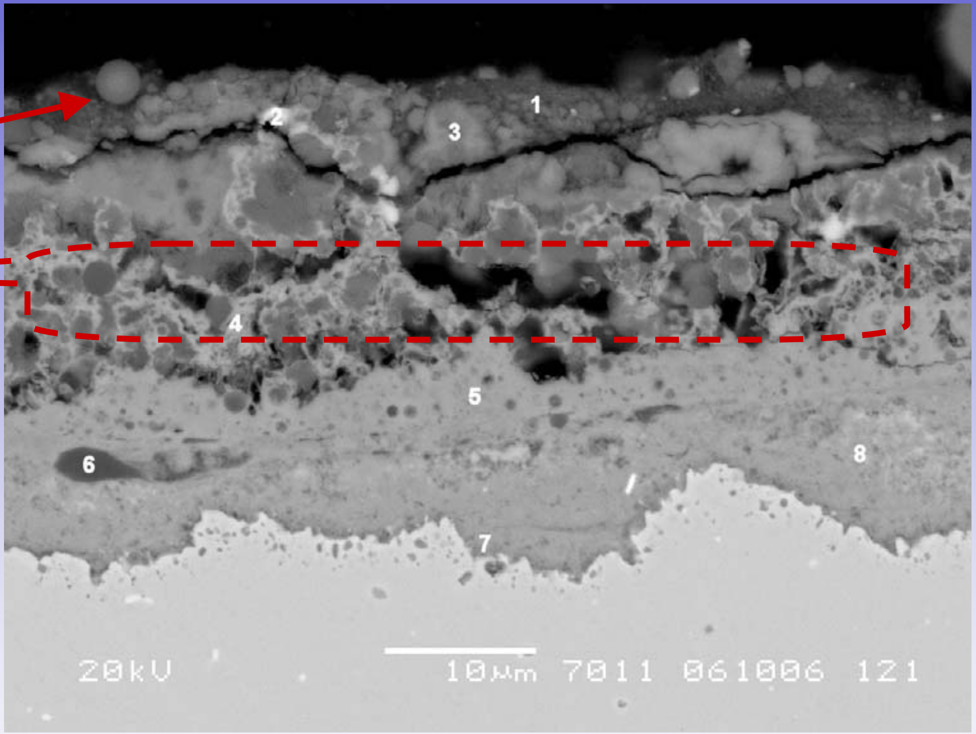
Corrosion studies – Test tube 347H

SEM image of test tube of 347H (pos. TC1)



SEM-EDX results

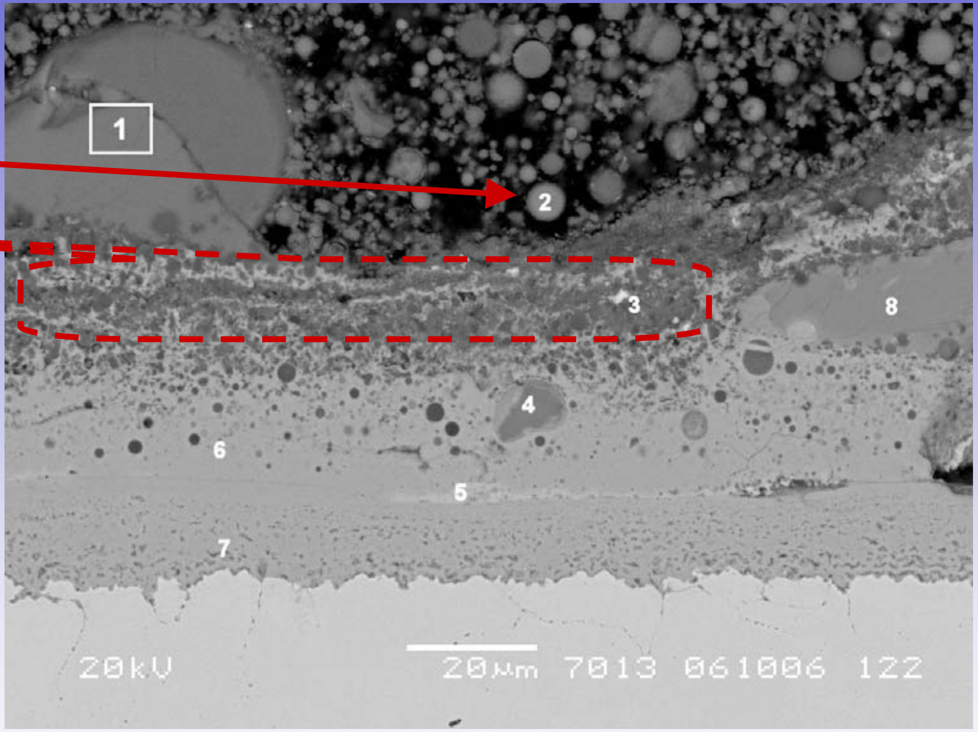
- Al, Ca & Si rich particles
- Inner deposit rich in Ca & S
- Outer oxide layer (#4,5): Fe-oxides
- Inner oxide layer (#7,8): Fe,Cr,Ni-oxides
- No traces of chlorine!!

Corrosion studies – Test tube 10CrMo910

SEM image of test tube of 10CrMo910 (pos. TC1)

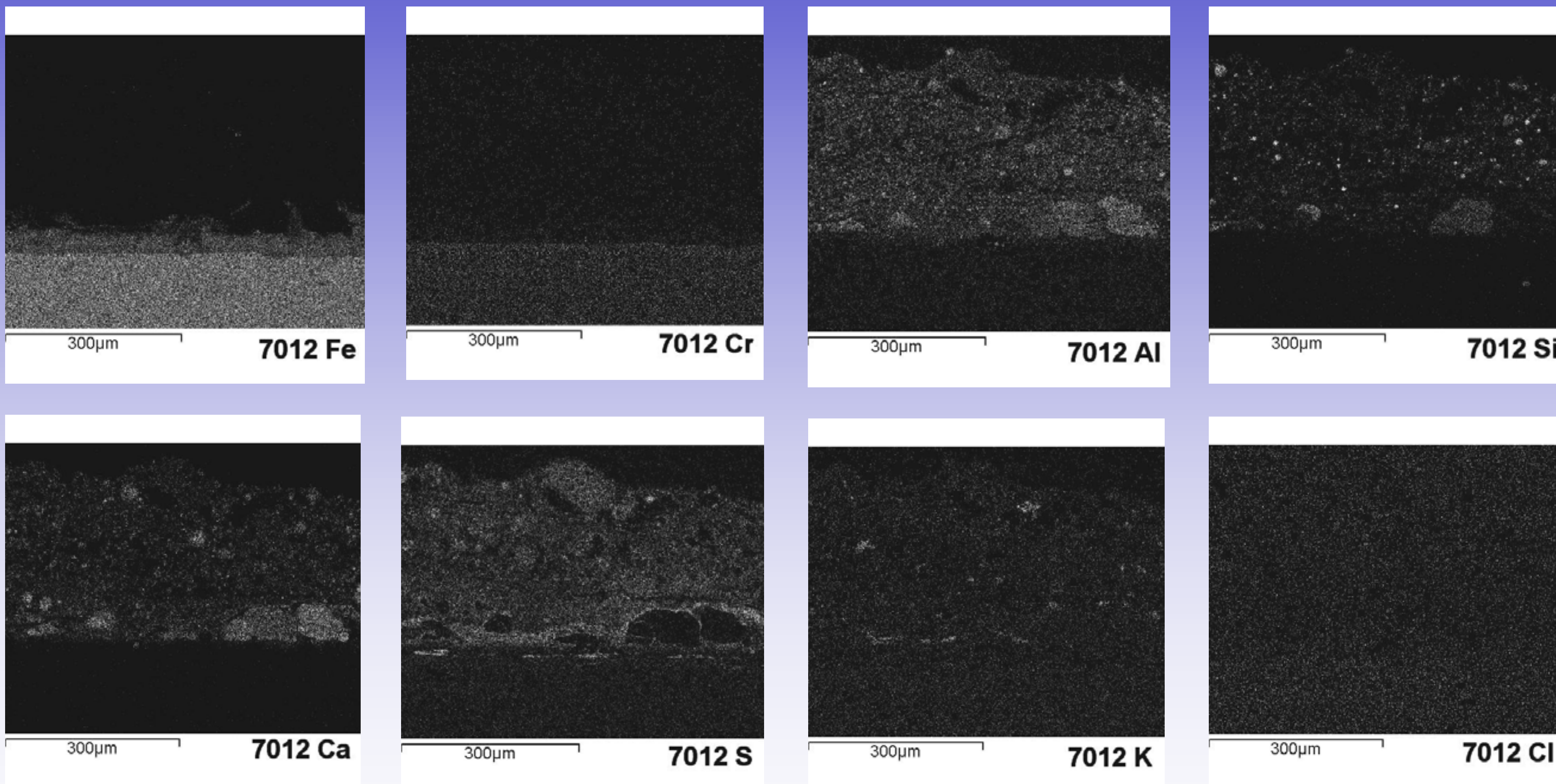
SEM-EDX results

- Al, Ca & Si rich particles
- Inner deposit rich in Ca, (K) & S
- Outer oxide layer(#8): Ca, Fe-oxides
- Inner oxide layer (#5-7): Cr, Fe & S
- S present throughout deposit
- No traces of chlorine!!



Corrosion studies – Element mapping

Test tube of 10CrMo910 (pos. TC1)



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Conclusions – #1

- A 1675 hours co-firing test with up to 5%-weight SWG has been successfully completed at Ottumwa Generation Station
- The deposition investigation indicated that:
  - The deposition flux to the super/re-heaters was unaffected by co-firing
  - The chemical composition of the deposits was not significantly influenced
  - A marginal increase in the concentration of water-soluble potassium of the deposits and fly ash was observed
  - Generally, the effects of co-firing 5% SWG were low compared to that of variations in the coal composition

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Conclusions – #2

- The conducted corrosion studies indicated that SWG co-firing (up to 5%-weight) had virtually no influence on the corrosion behavior:
  - No evidence of chlorine-induced corrosion was observed
  - Only small amounts of potassium was found in the inner deposits
  - Sulfur played a dominating role in the corrosion mechanism. The sulfur input with SWG is negligible compared to that of the coals
  - No distinct difference in the corrosion resistance was observed between the four steel materials tested

Acknowledgements

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