Deposition Mechanisms of High Chlorine Coal as a Function of Stoichiometry and Tube Temperature

Shrinivas Lokare, J. David Dunaway, Doug Rogers

Dale R. Tree, and Larry Baxter

Brigham Young University

Helle Junker

Techwise, Denmark

Wait Bakker, Arun Mehta

Electric Power Research Institute, EPRI

Sponsored By: EPRI, U.S. DOE, National Renewable Energy Laboratory, Techwise

Introduction

Chlorine is a known corrosion enhancing element which is found in coal and biomass fuels

- The role of chlorine in boiler corrosion is not well understood
- The majority of data involves corrosion measurements for simulated combustion gas containing HCl where results are mixed related to the importance of chlorine.
- Recently increased corrosion rates have been observed in fuel rich regions of boilers burning high chlorine (0.4 %) coal.

Introduction

- Equilibrium calculations by Baxter et al. (2001) suggest alkali chlorides are the most stable form of Chlorine at combustion temperatures.
- Once formed at high flame temperatures, we hypothesizes that Alkali Chlorides such as NaCl, KCl will:

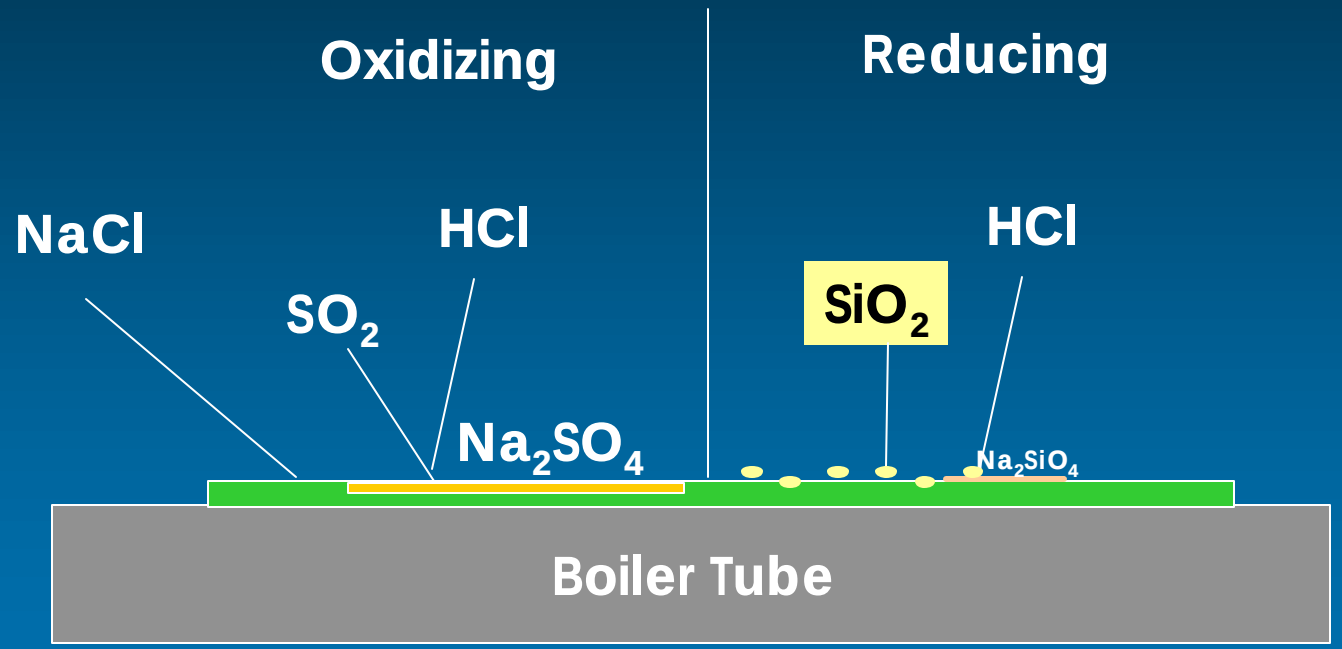
  1) May condense on tube surfaces in non-equilibrium states

  2) Under oxidizing conditions they will then react to form alkali sulfates releasing chlorine as HCl in relatively short time periods (minutes to hours)

  3) Under reducing conditions reach equilibrium as alkali silicates releasing HCl only after long time periods (days)

- NaCl deposits increase corrosion rates by a factor of 4 (Daniel, 1991)

Chlorine Deposition Mechanism



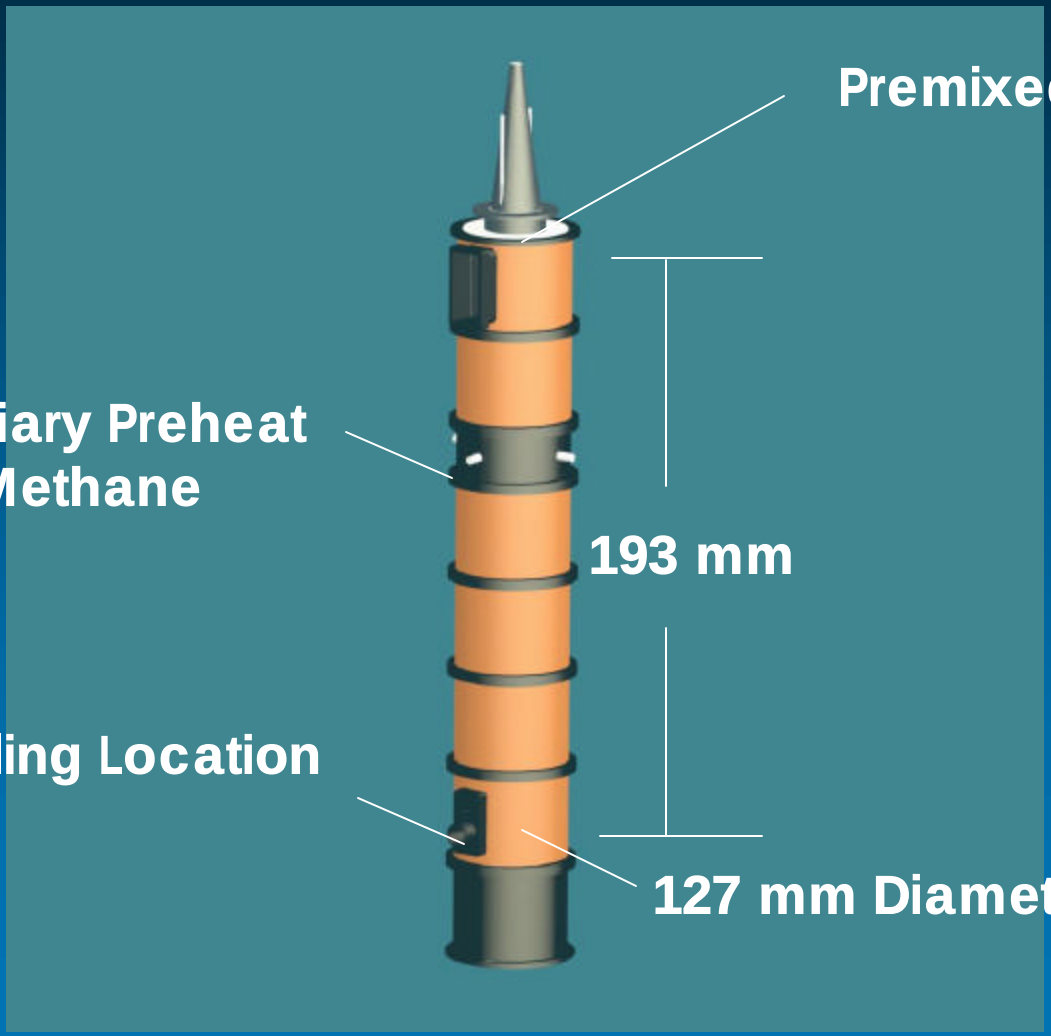
Objectives

Demonstrate the proposed deposition mechanism experimentally

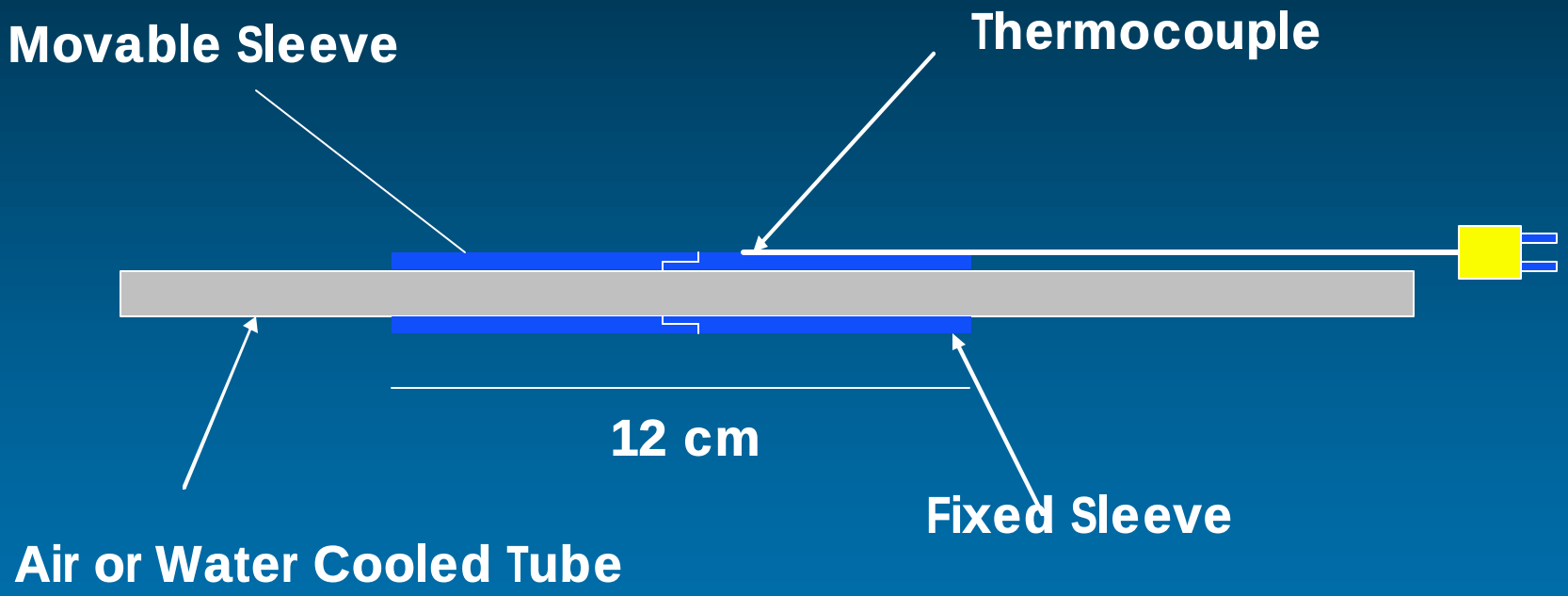
- Collect ash samples on simulated boiler tubes and determine the composition of the samples using SEM analysis
- Measure elemental composition of the fuels
- Using the SEM identify Chlorine, Sulfur, Sodium, Potassium and Silicon content
- Compare deposit composition to results expected from equilibrium calculations

Method

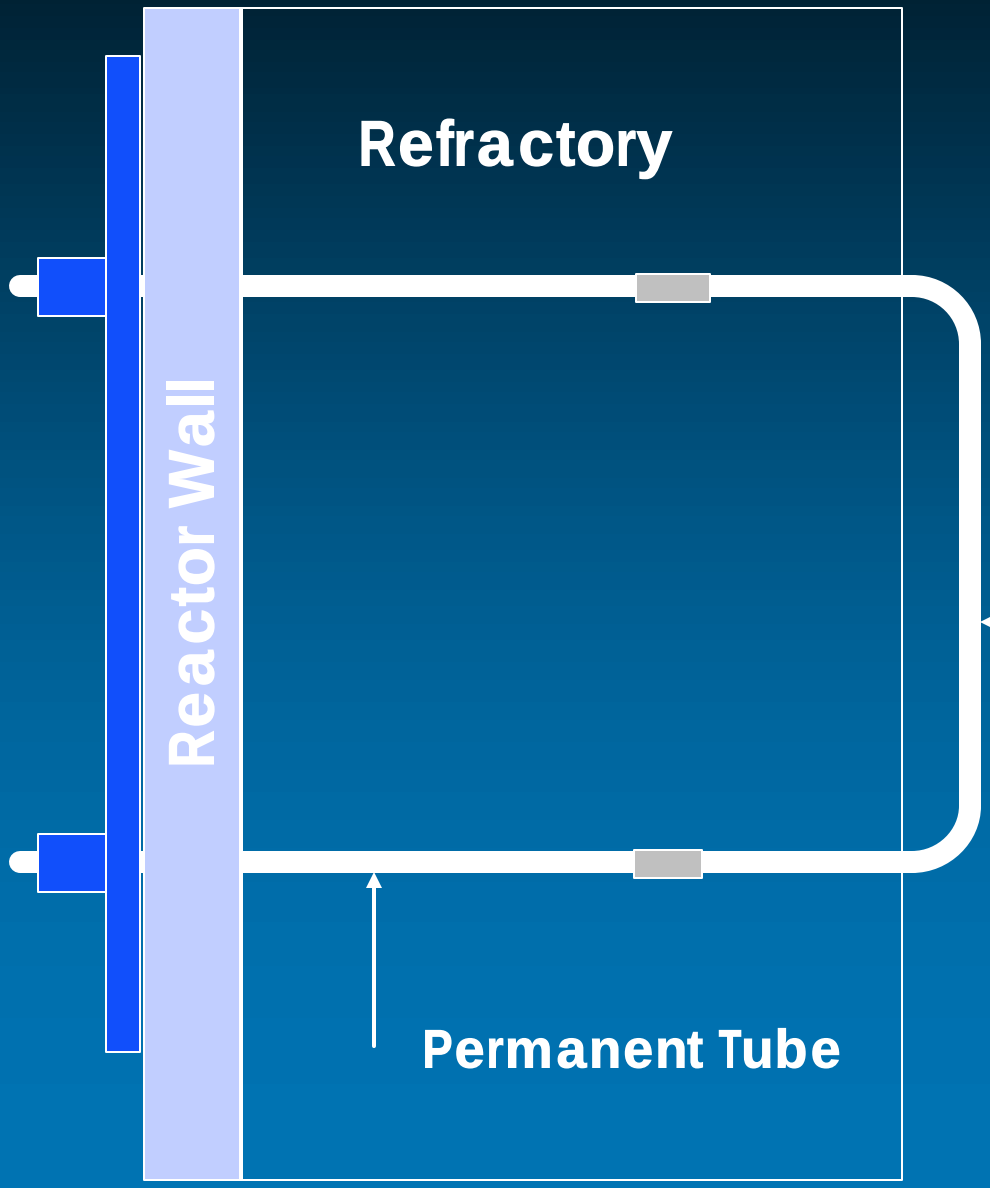
Multifuel Reactor



Method – Cross-flow Probe



Method – Parallel-flow Probe



Reactor Flow

Sacrificial Water or
Air Cooled tube

Tube diameter = 9.5 mm

Exposed Length = 12. 7 cm

Method – Fuels

Biomass Fuels

- Straw
- Grain Screenings
- Sawdust
- Sugarbeet pulp
- Shea nut shells
- Sunflower shells
- R1 – R14 Fuel blends and additives

Coal Fuels

- Illinois # 6
- Sub-bituminous, Powder River Basin

Method – Fuel Properties

Chlorine, Potassium, Silica

Straw

50 - 50 Mix

Cl, S, K	Cl, S, K	Cl, s, k	K, Na
Sunflower Shells	**Shea Nut Shells**	**Sugarbeet Pulp**	**Sawdust**

50 - 50 Mix

Grain Screenings

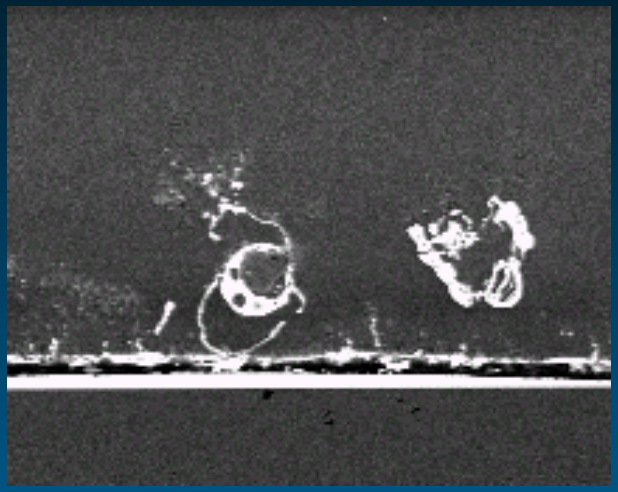
Chlorine, Phosphorus, Potassium. Silica, Sodium

Method – Fuel Properties

Illinois # 6,
Cl = .4%, Avail. Na = 0.45% , S= 0.95%

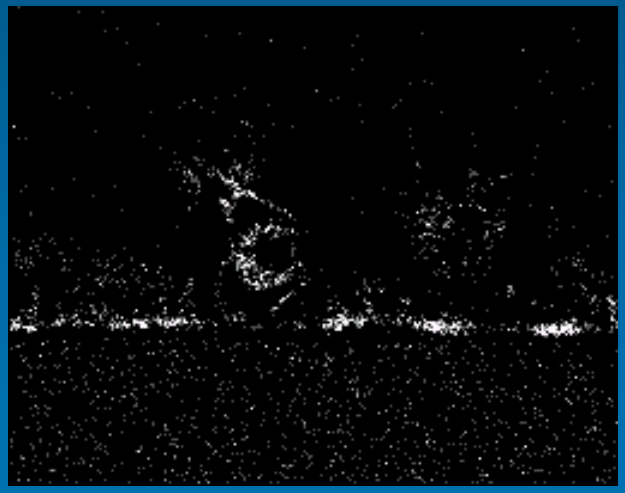
Wyoming PRB
Cl = .08%, Avail. Na ~ 0.09% , S = .65%

Results- Straw

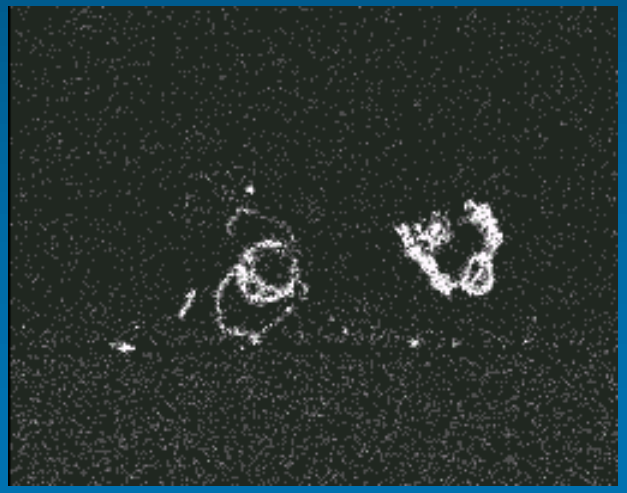


Backscatter

Chlorine

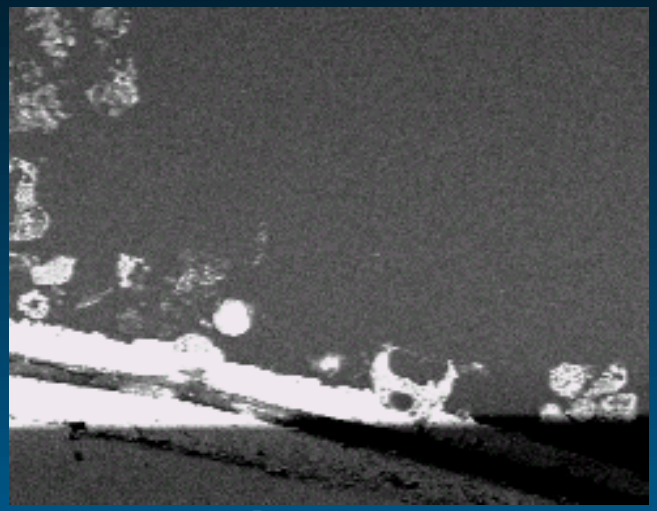


Potassium

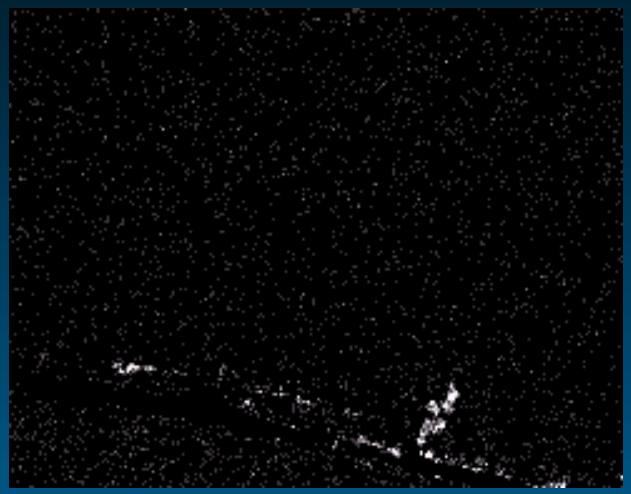


Silicon

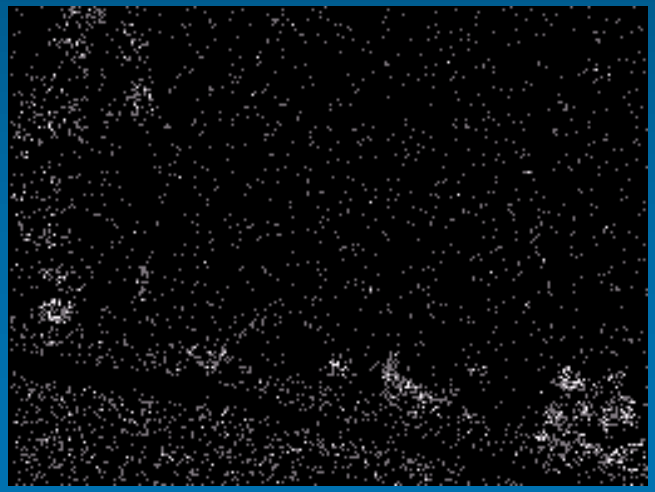
Results- Sawdust



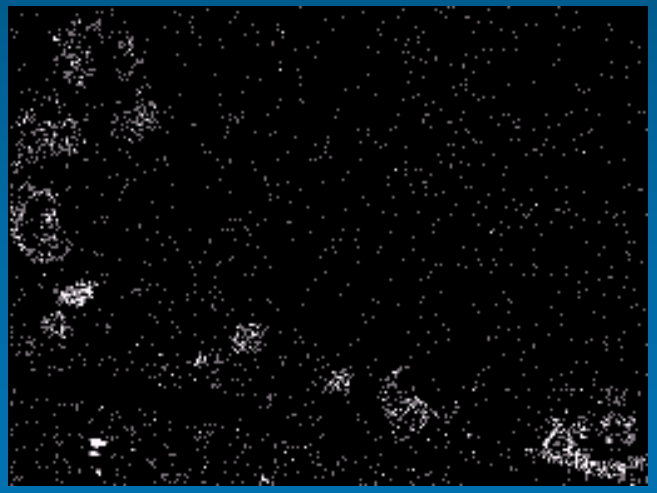
Backscatter



Chlorine

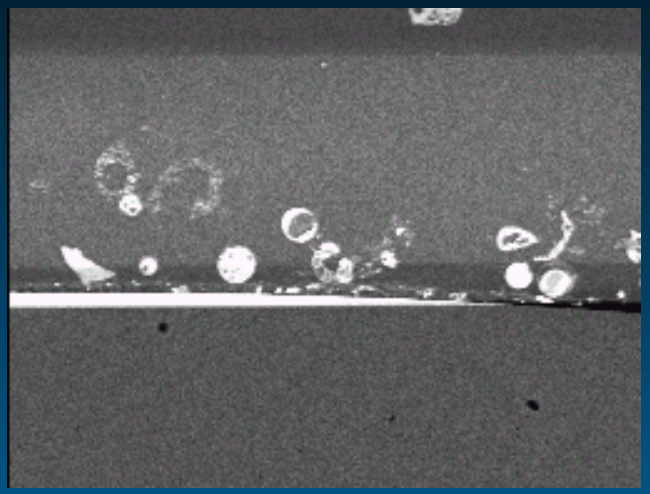


Potassium

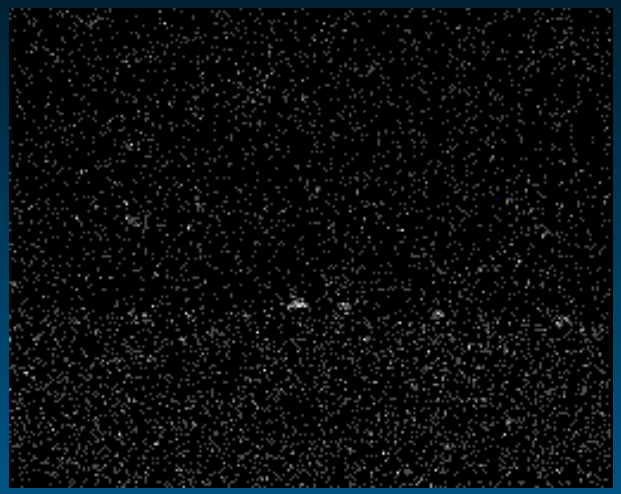


Silicon

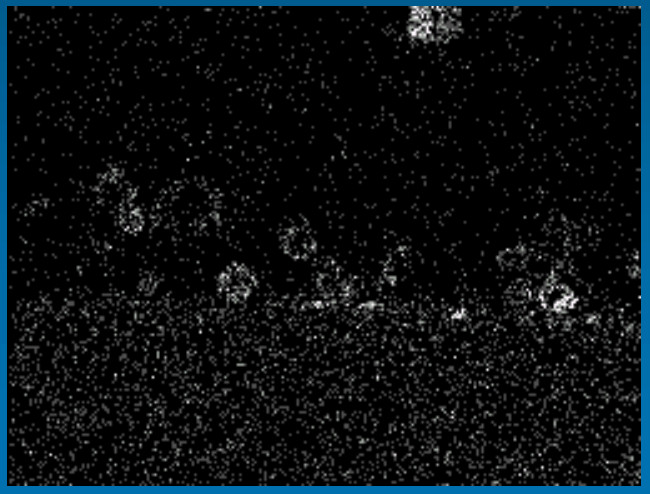
Results- 50% Straw 50% Sawdust



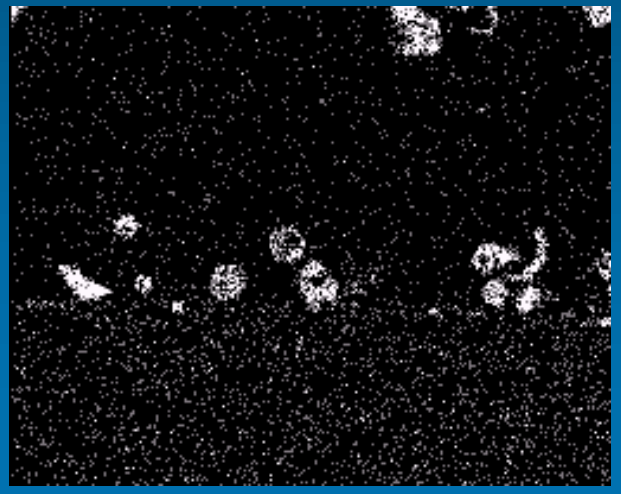
Backscatter



Chlorine

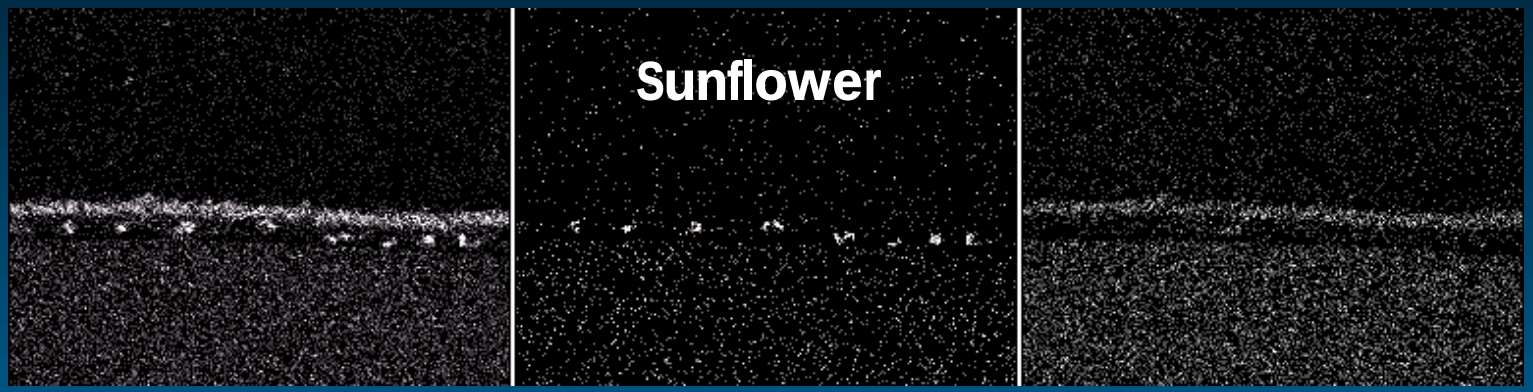


Potassium

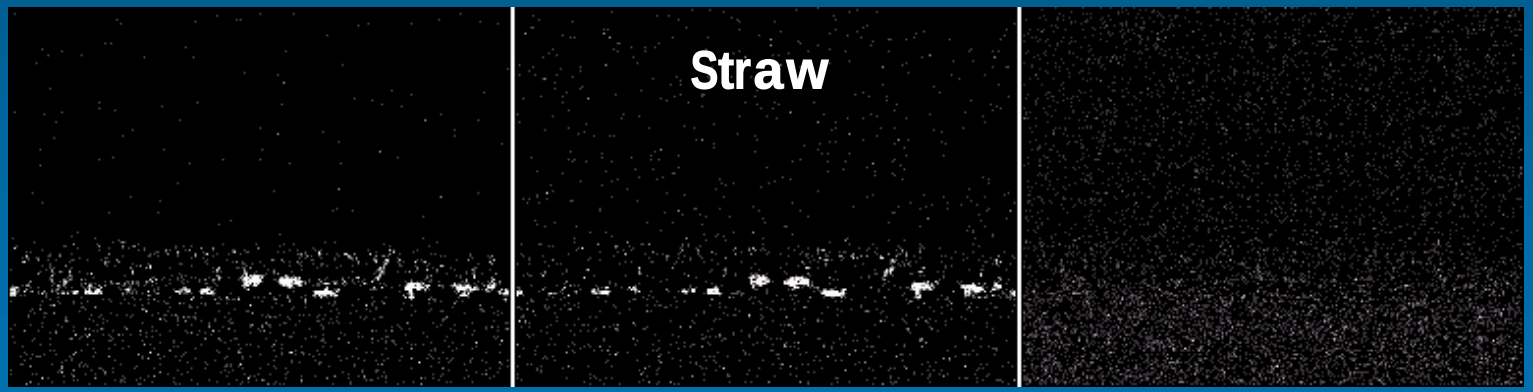


Silicon

Results- Sunflower (top) and Straw (bottom)

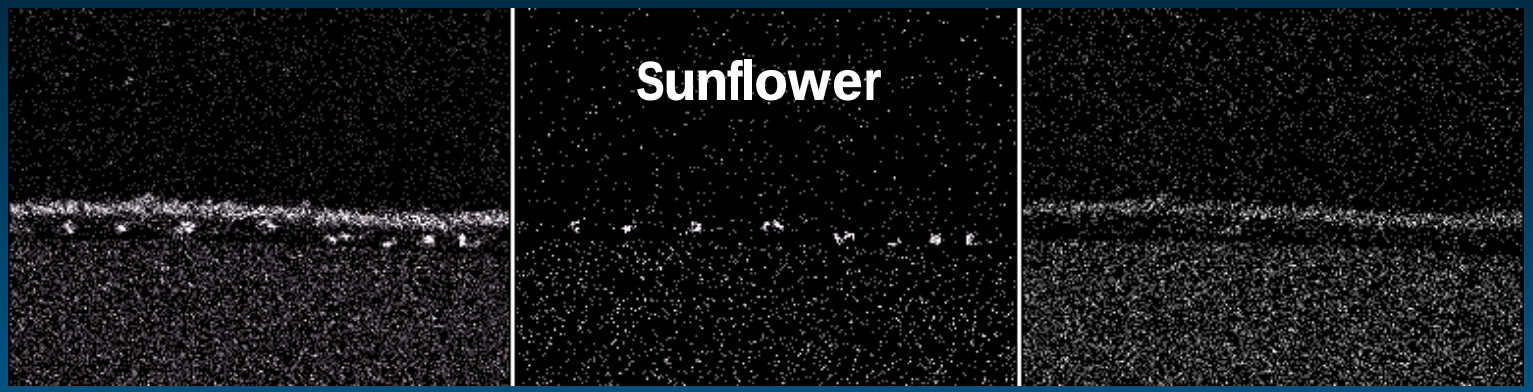


Potassium Chlorine Sulfur

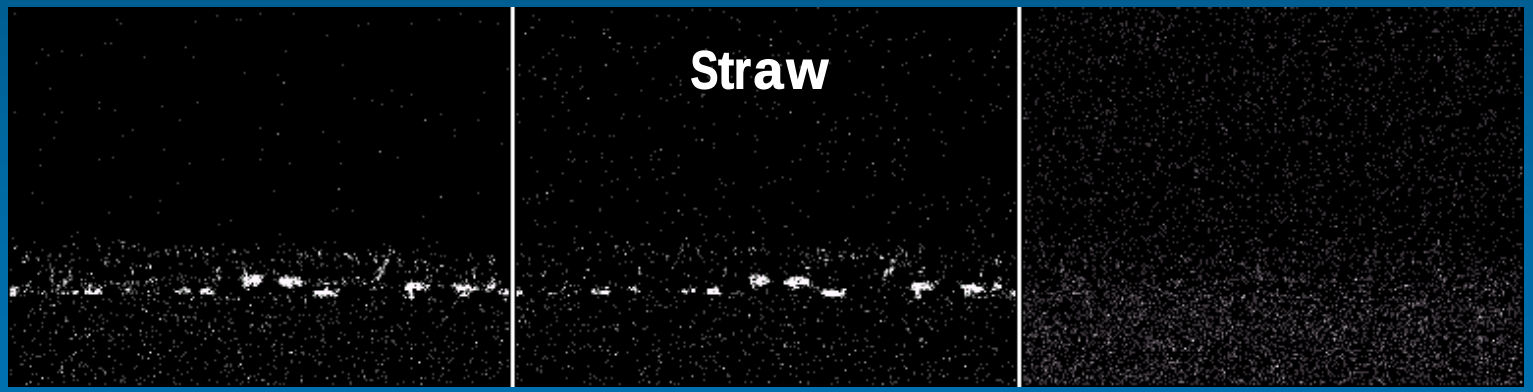


Potassium Chlorine Sulfur

Results- Sunflower (top) and Straw (bottom)

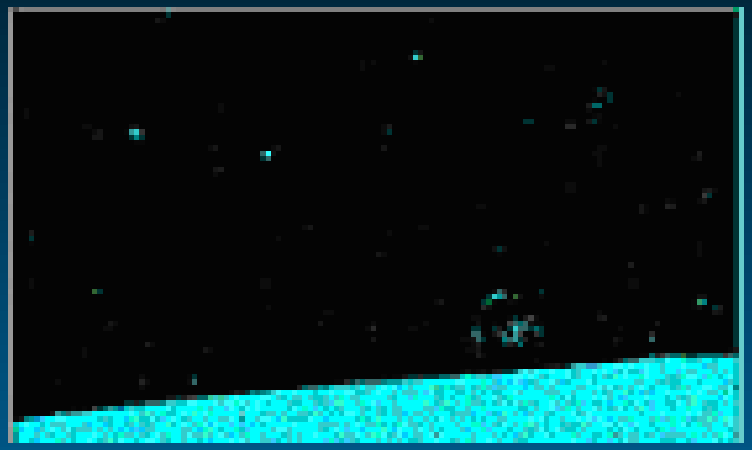


Potassium Chlorine Sulfur

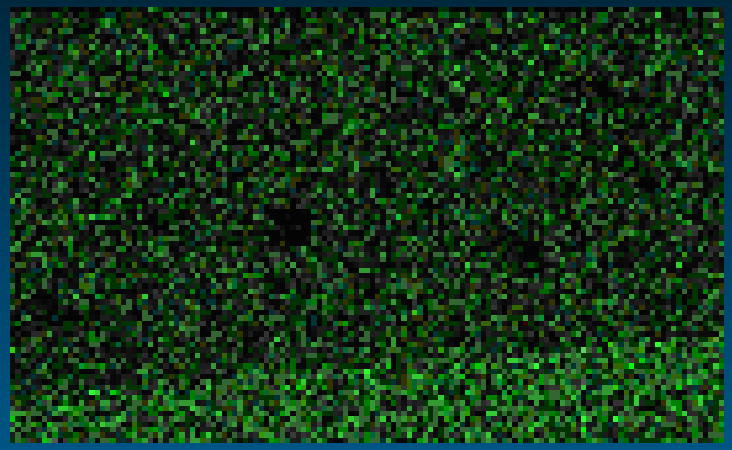


Potassium Chlorine Sulfur

Results – Coal, Reducing, High Chlorine



Iron

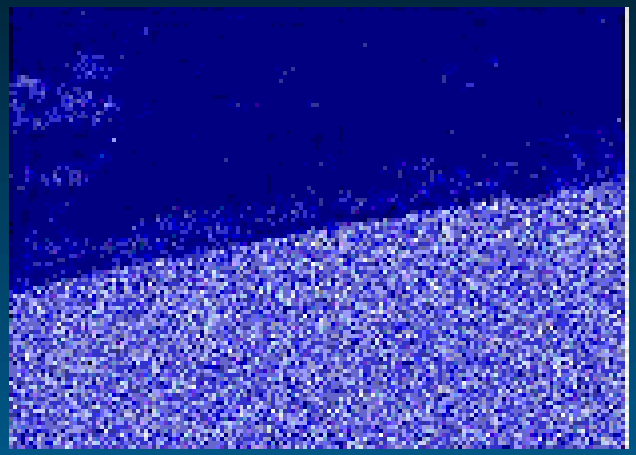


Chlorine

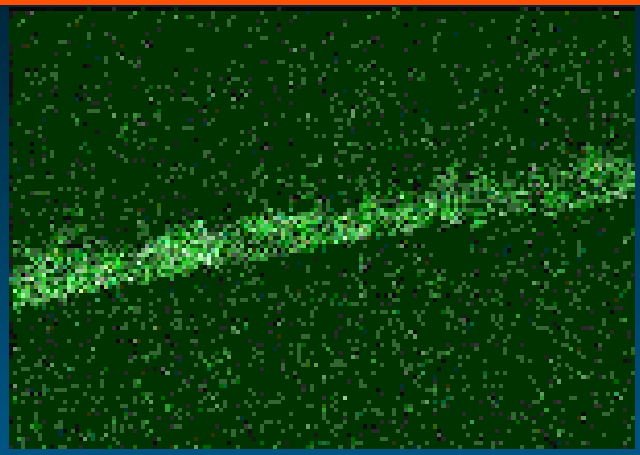
Potassium

Sulfur

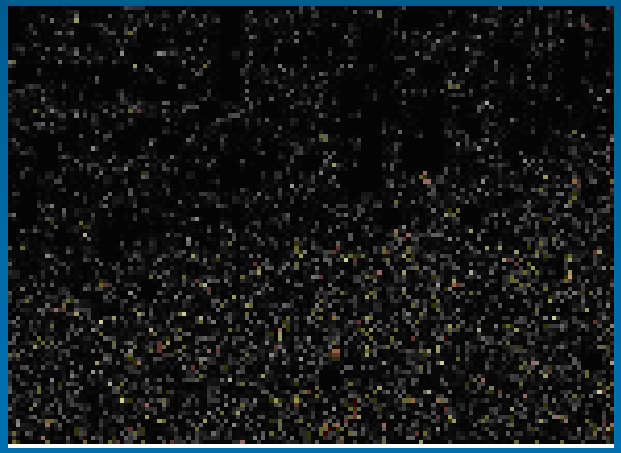
Results – Coal, High Chlorine, 98 ºC Tube Temperature



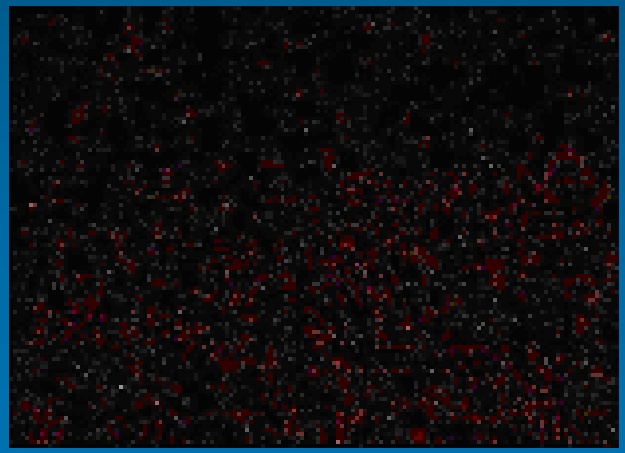
Iron



Chlorine

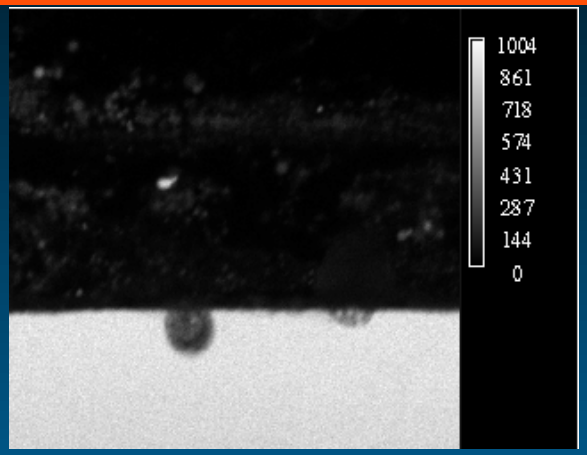


Potassium

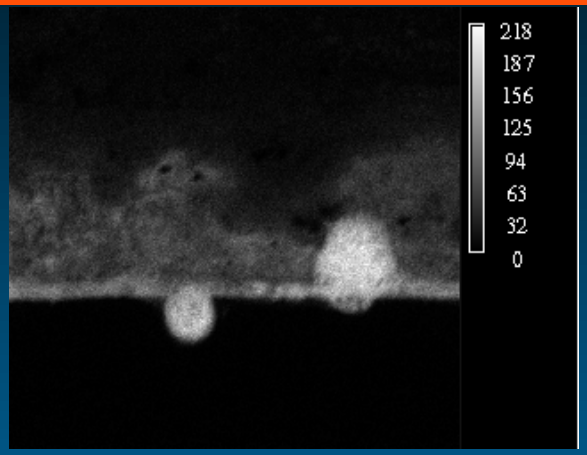


Sulfur

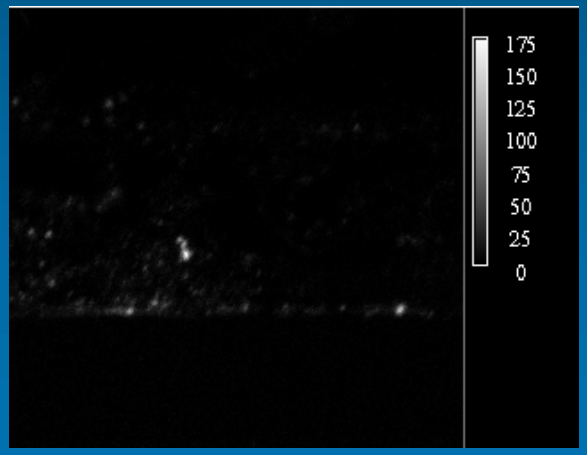
Results – Coal, High Chlorine, 98 ºC Tube Temperature



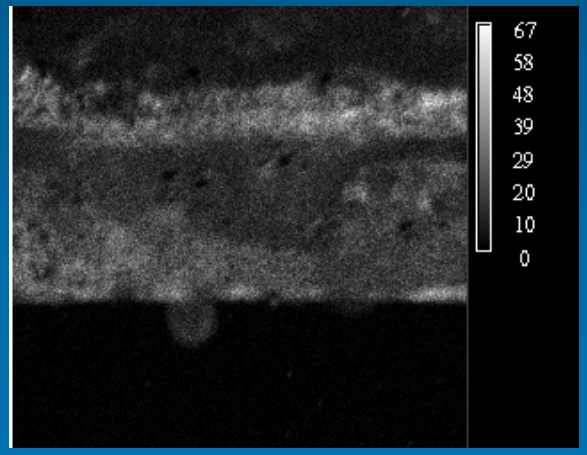
Iron



Chlorine



Calcium



Sulfur

Conclusions

- Experimental evidence supports conclusions based on equilibrium calculations regarding chlorine deposition
- Alkali chloride deposits were found on tube surfaces under reducing conditions
- Under oxidizing conditions, sulfur layers were found in addition to reduced chlorine layers
- Coal did not produce an alkali chloride layer at typical boiler tube temperatures (450 ºC) when burning coal
- The actual dew point temperature and importance of available alkali in the coal are yet to be found