

REINHOLD ENVIRONMENTAL Ltd.



2011 APC Round Table & Expo Presentation

July 11-12, 2011, in Cleveland, OH / Hosted by FirstEnergy

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Ljungström® Air Preheater Low Gas Outlet Temperature (LGOT) R&D Program

Strategy to Improve Air Preheater Performance via.
SO₃ Mitigation – Workshop 5

Kevin J. O'Boyle

APC Round Table Conference – July 11, 2011

POWER

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Background for the LGOT R&D Program

Evolution of Air Preheater Fouling Solutions

Results and Conclusions from Laboratory Testing

Plans for Full Scale Field Demonstration

Increasing Heat Recovery and Reducing Gas Outlet Temp.

- Future of Coal
 - Global Warming – Climate Change
 - Environmental opposition to new plants
 - Regulatory uncertainty – Cap & Trade?
 - Escalating environmental concerns
 - NO_x, SO_x, PM_{2.5}, Mercury and CO₂
- Air Preheater & Boiler Efficiency is Key
 - Higher is better, unless it impacts availability.
 - Greater heat recovery can reduce coal consumption and emissions.
 - Reduced flue gas temperatures can reduce SO₃ emissions and enhance the capture of fly ash and mercury.
- Air Preheater Availability
 - Fouling and plugging of the air preheater

Ljungström® Air Preheater - Part of the Solution

Background for the LGOT R&D Program

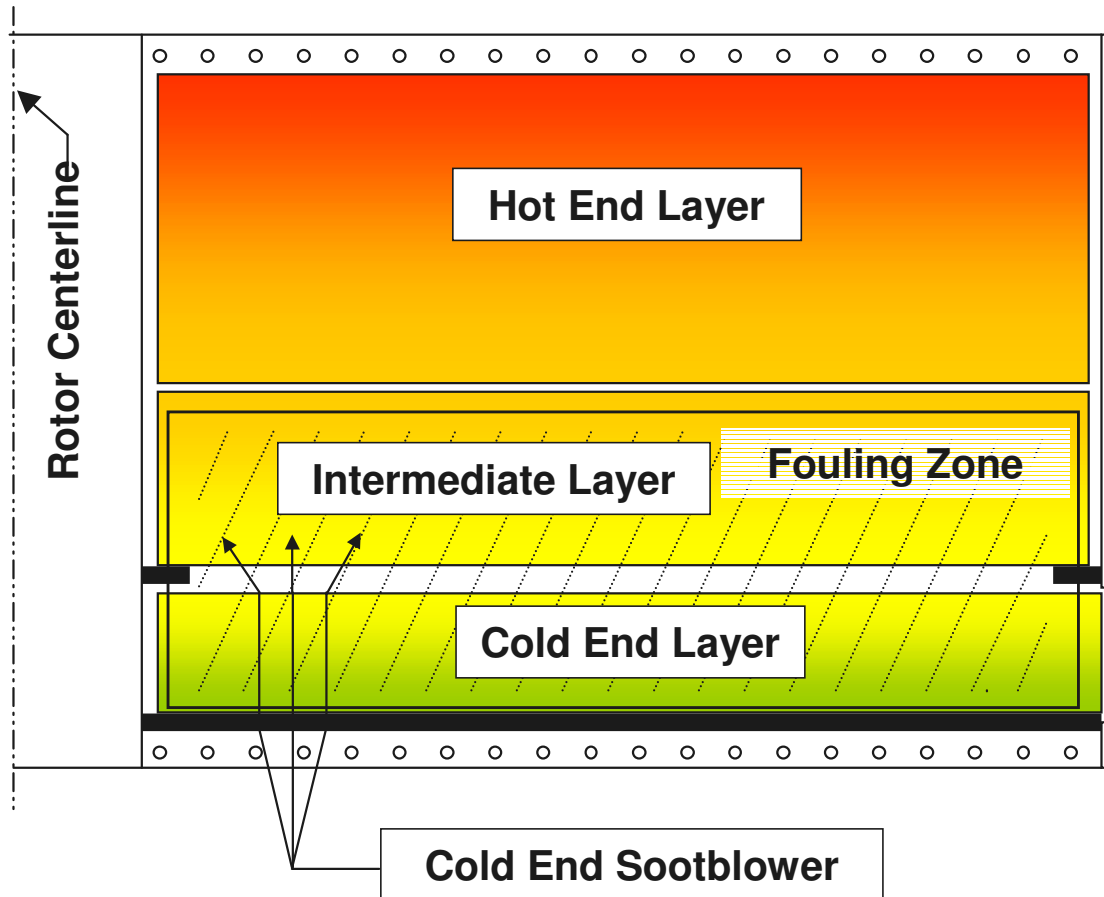
Evolution of Air Preheater Fouling Solutions

Results and Conclusions from Laboratory Testing

Plans for Full Scale Field Demonstration

Increasing Heat Recovery and Reducing Gas Outlet Temp.

Traditional Rotor Configuration



Fouling Problems

- Soot Blower penetration limited
- CE grating blocks cleaning media



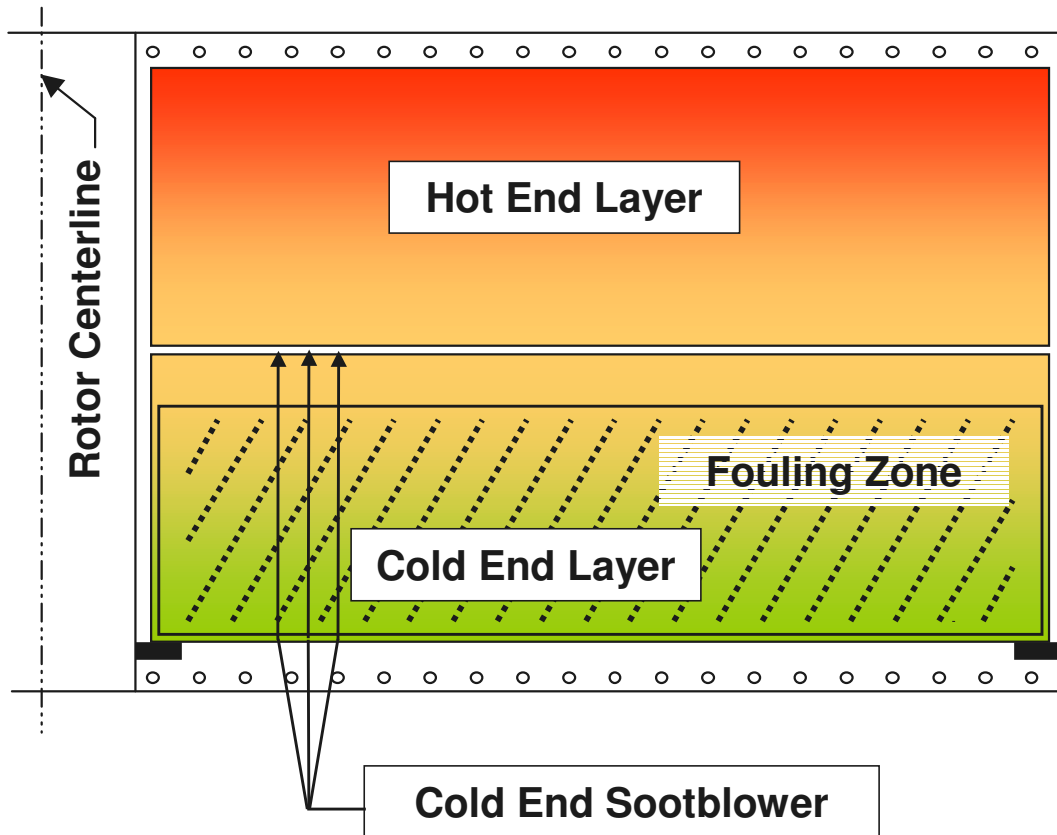
- S/B energy lost between layers
- Open channel surface (DU)



- Fouling deposits grow in size
- Pressure drop increases
- Unplanned outage to water wash

Fouling Concerns with the Traditional Configuration

ClearFlow™ Rotor Configuration



Fouling Solution

- DNF® closed channel element in CE



- Fouling deposits in deep CE layer
- Deposits closer to the sootblower
- Cleaning obstructions are minimized



- Enhanced sootblower effectiveness
- Fouling impact minimized

Fouling Solution - Current State of the Art

- Fouling is manageable on existing units with most fuels, and at gas outlet temperatures down to 280-260 °F.
- Our objective is to approach 220 °F gas out with stable operation and no loss in availability.
 - Increased boiler efficiency and reduced coal consumption on new and existing units
 - Reduced emissions, including CO₂, on new and existing units
 - Maintain stable operation without the need for additional water wash cycles

Advancing the State of the Art

Background for the LGOT R&D Program

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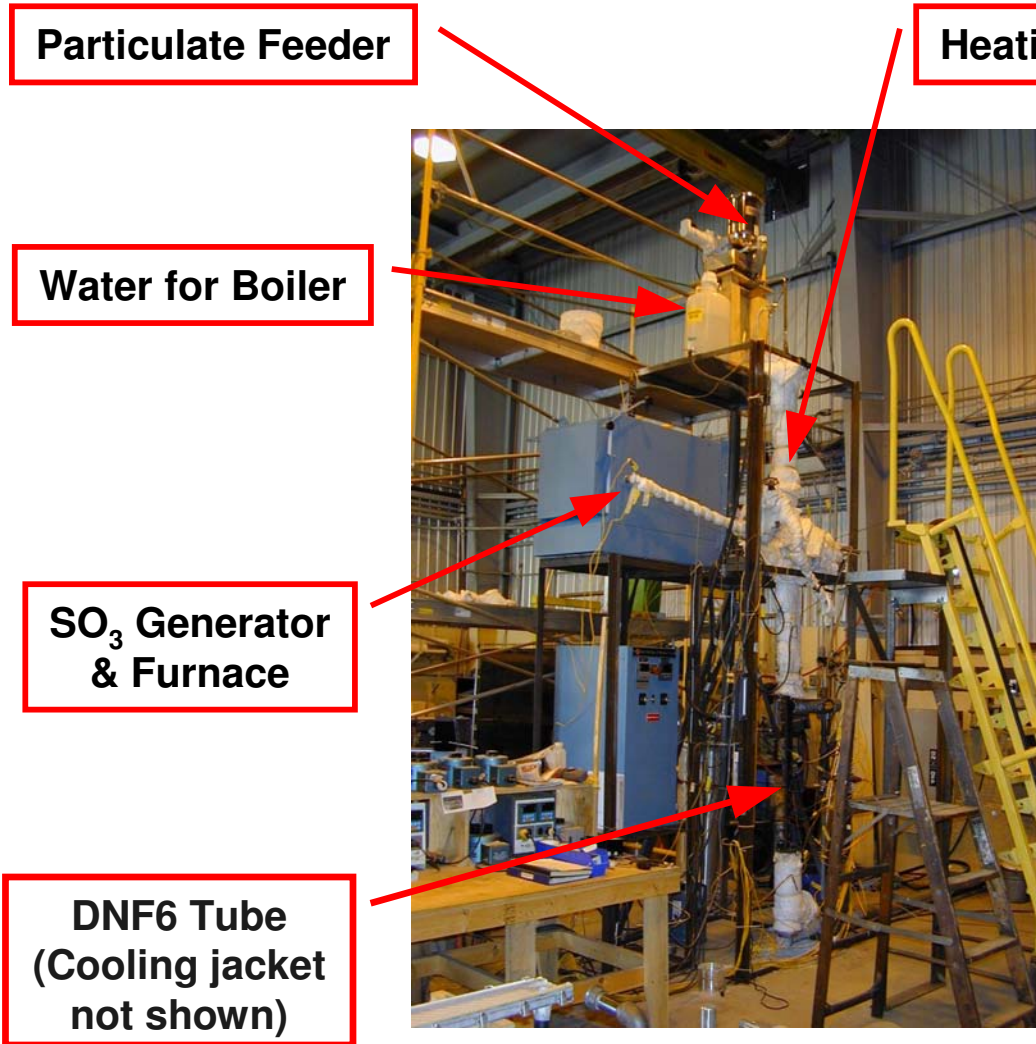
Plans for Full Scale Field Demonstration

Increasing Heat Recovery and Reducing Gas Outlet Temp.

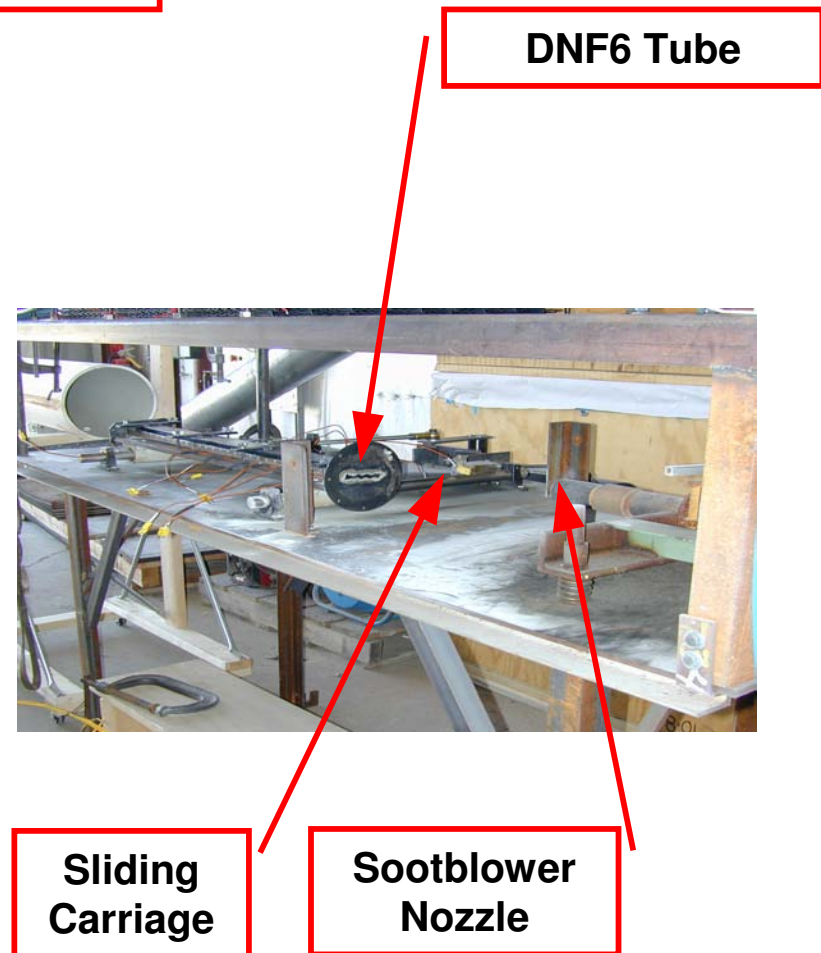
- Bench Scale Testing
 - Single channel heat exchanger from DNF6™ element
 - Short-term tests to study acid condensation & particulate fouling
 - Included pressure drop measurements & offline soot blowing
 - Simulated flue gas was air, 10% H₂O, SO₃ & inert particulate
 - Exit gas temperature was 210°F
 - Deposit weights were measured before and after soot blowing
- The Bulk Acid Ratio was a useful correlating parameter

$$\text{Bulk Acid Ratio} = \left(\frac{M H_2SO_4 \text{ Condensed}}{M \text{ Entering Particulate}} \right) \times 100$$

Bench-Scale Test Apparatus



Fouling Test Apparatus

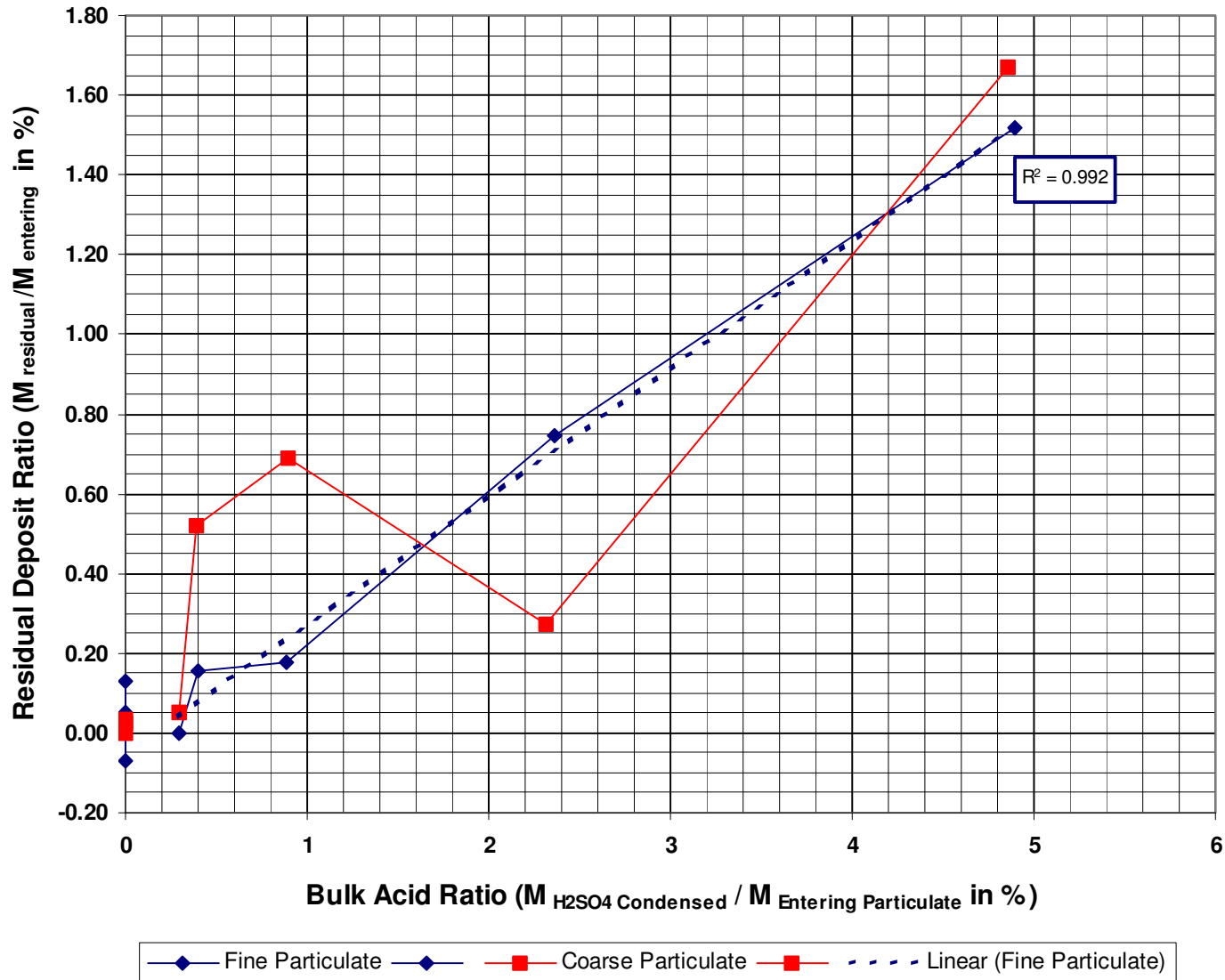


Soot Blowing Simulator

Bench Scale Deposit Results



Soot Blowing Results Bench Scale DNF6 Fouling & Cleaning Tests



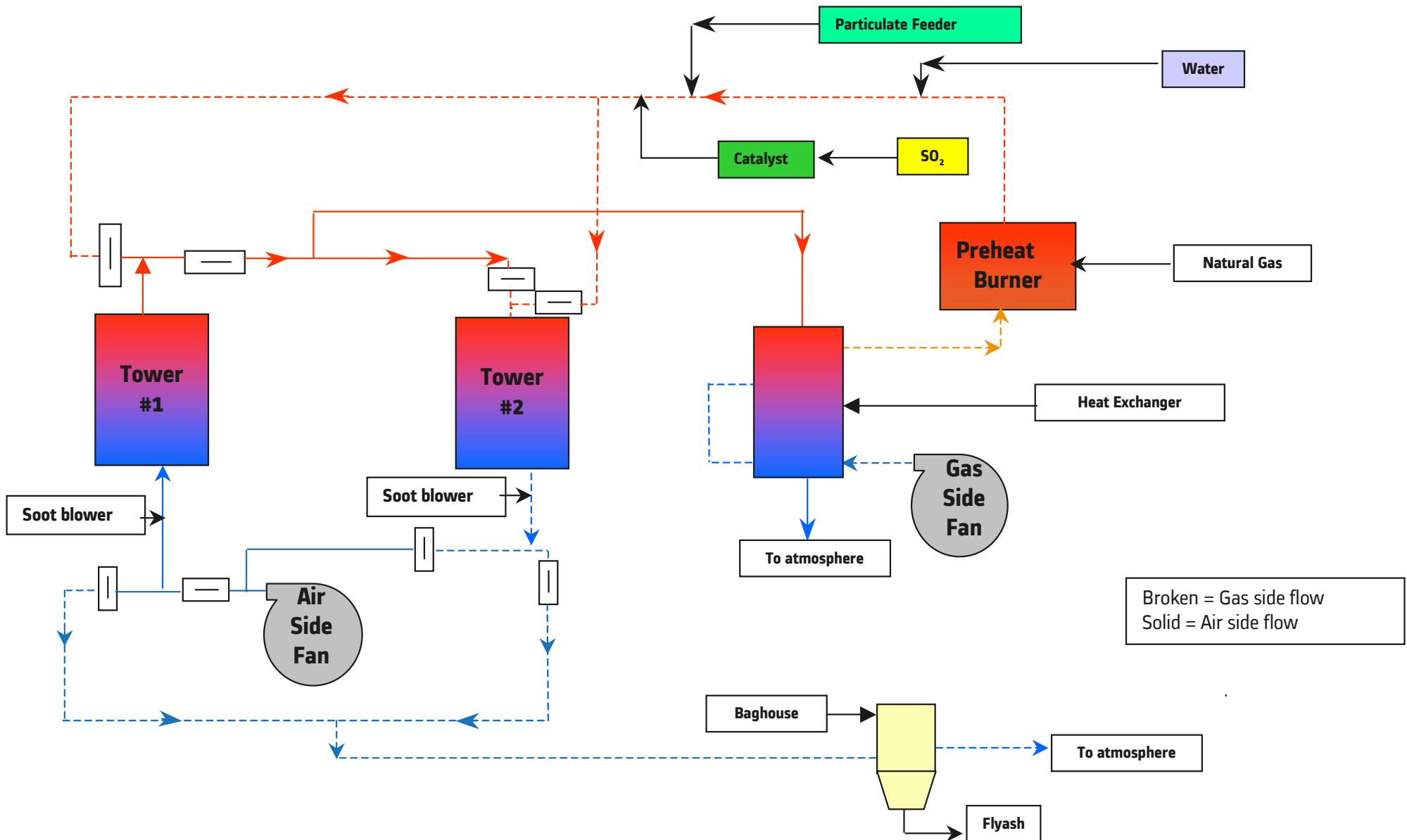
Conclusions from Bench Scale Testing

- As the bulk acid ratio increased, residual deposits increased.
- Even at very low bulk acid ratios, residual deposits remained after soot blowing.
- Based on a 50% increase in gas side pressure drop in one year...
 - The allowable bulk acid ratio was found to be $\leq 0.3\%$.
 - Many coals would require some form of SO₃ mitigation.

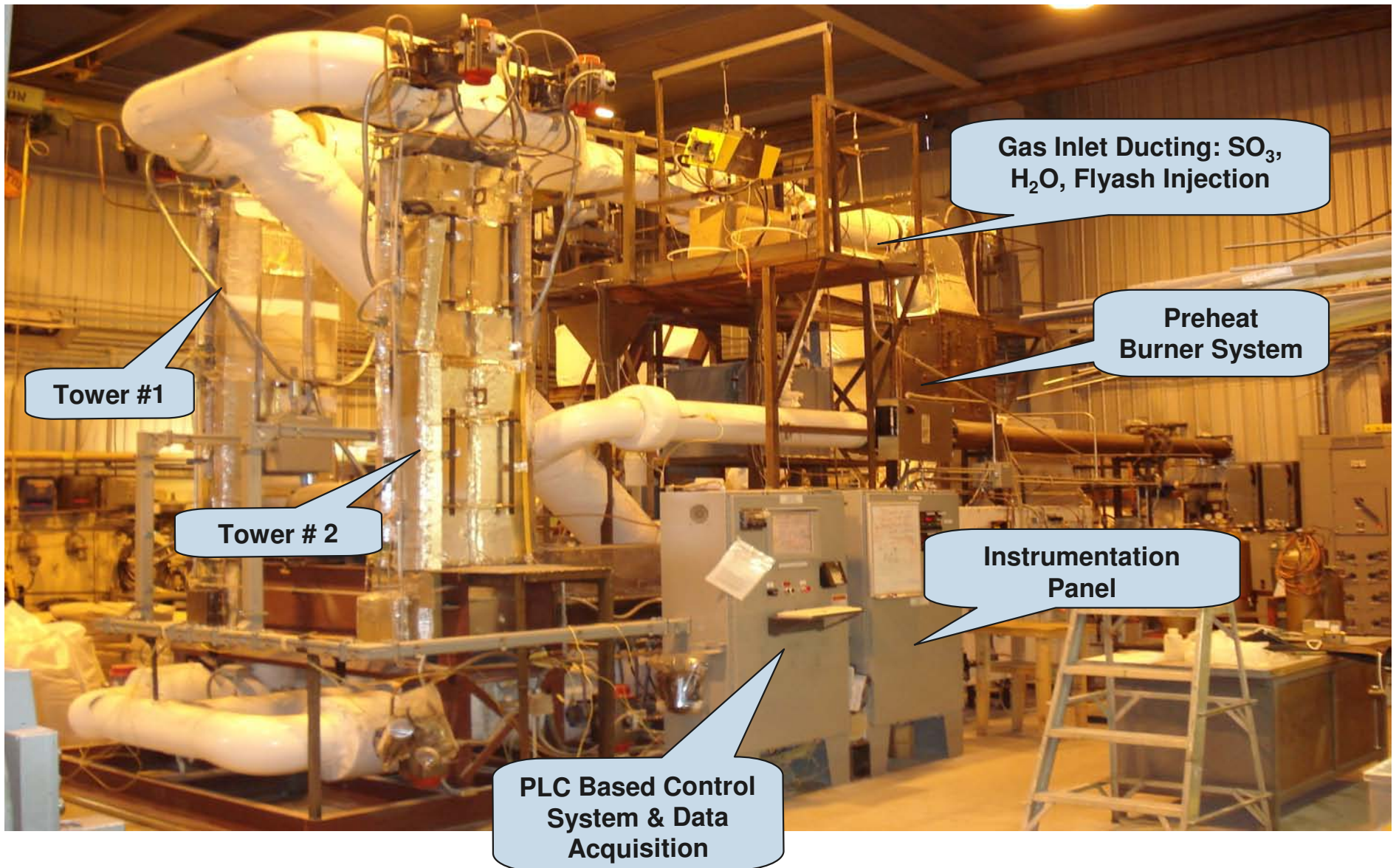
Fly Ash Loading	1	2	3	4	5	6	gr/scf
Minimum Operating Time	12	12	12	12	12	12	months
Allowable Bulk Acid Ratio	0.3	0.3	0.3	0.3	0.3	0.3	%
Allowable SO₃ Concentration	2	3	5	7	8	10	ppmv

- Pilot Scale Testing
 - Switching regenerator with DNF6 element cores (cold end)
 - Better simulation of the operation of a Ljungstrom® air preheater
 - Provided full range of element temperatures simulating 1 RPM
 - Element and deposits were also exposed to clean, counter flow air
 - Long-term tests with simulated flue gas (air, H₂O, SO₃ & fly ash)
 - PLC control system for 24 / 7 operation and control
 - Online pressure drop measurements & online soot blowing at the cold end (3 cycles / 24 hours)
 - Gas outlet temperature was 220 °F

Pilot Scale Test Apparatus



Pilot Scale Test Apparatus



Pilot Scale Testing – Simulated Sodium Based SO₃ Mitigation



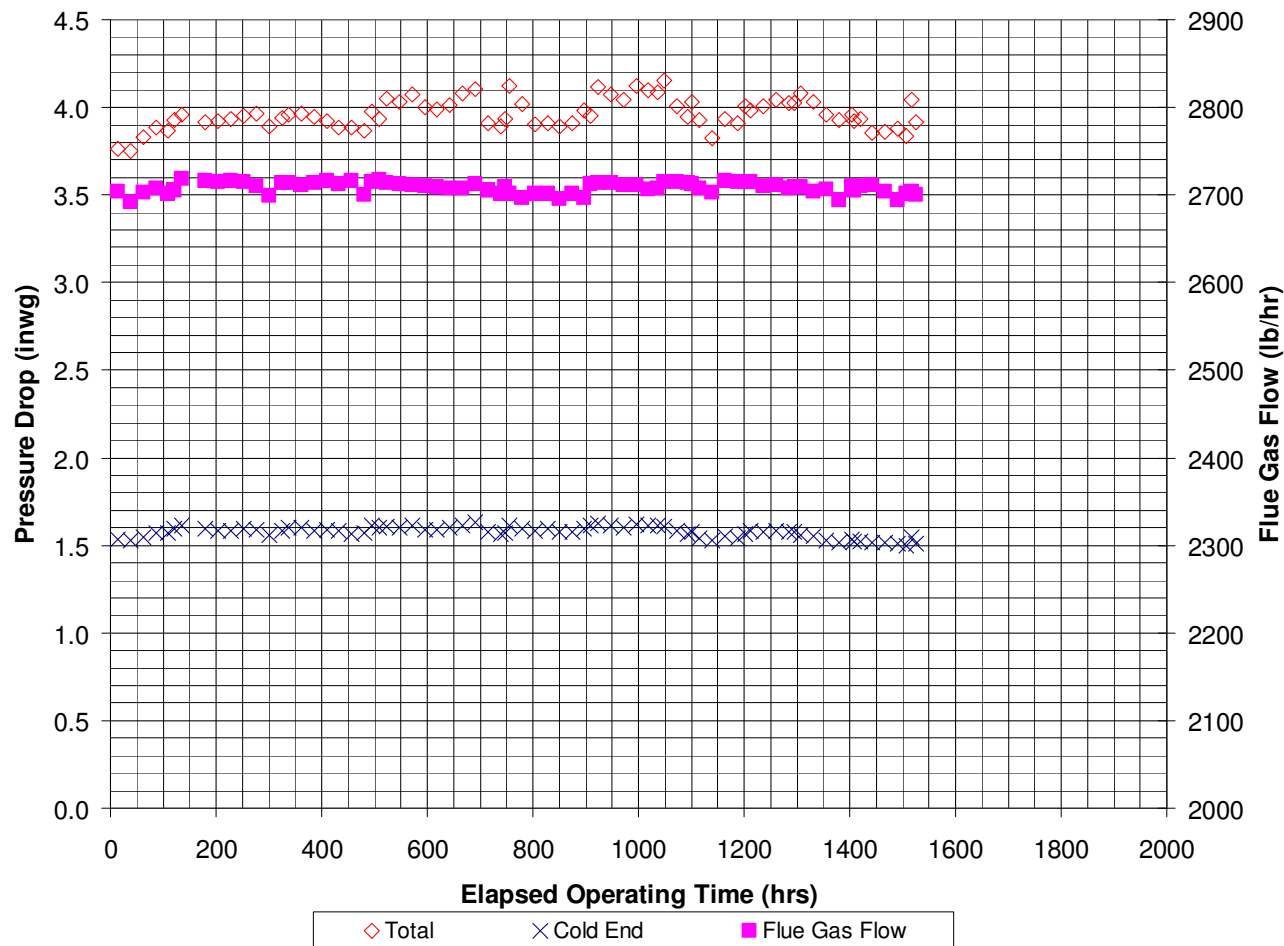
Parameter		
Test Duration (hours)	1525	714
Cold End Element	DNF6	DNF6
Flue Gas Inlet Temperature (F)	592	592
Average Flue Gas Outlet Temp. (F)	220	220
Flue Gas Flow Rate (lb/hr)	2710	2700
Fly Ash Injection Rate (lb/hr)	20	20
Sodium Sulfate Injection Rate (lb/hr)	0.95	0.95
Water Content by Volume (%)	9.0	9.5
SO ₃ Content by Volume (ppmv)	5	10
Flyash Loading (gr/scf)	3.7	3.7
Total Particulate (gr/scf)	3.9	3.9
Soot Blowing Freq. (cyc./day)	3	3

- Tests simulated flue gas resulting from 60 ppmv SO₃ mitigated to 5 & 10 ppmv with sodium based injection technology
- The SO₃ mitigation by-product sodium sulfate was added in powder form to the injected eastern bituminous fly ash
- These were air preheater fouling tests, not SO₃ mitigation performance tests

Simulated Sodium Based SO₃ Mitigation 5ppmv SO₃ with Added Sodium Sulfate

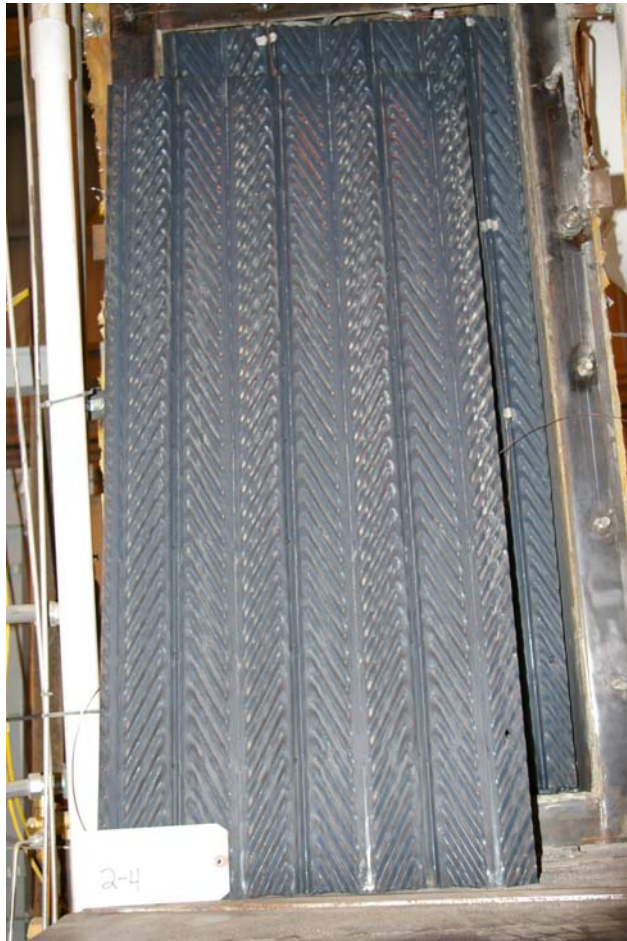


Tower 1 Gas Side Pressure Drops



Stable Pressure Drop Response

Simulated Sodium Based SO₃ Mitigation 5ppmv SO₃ with Added Sodium Sulfate

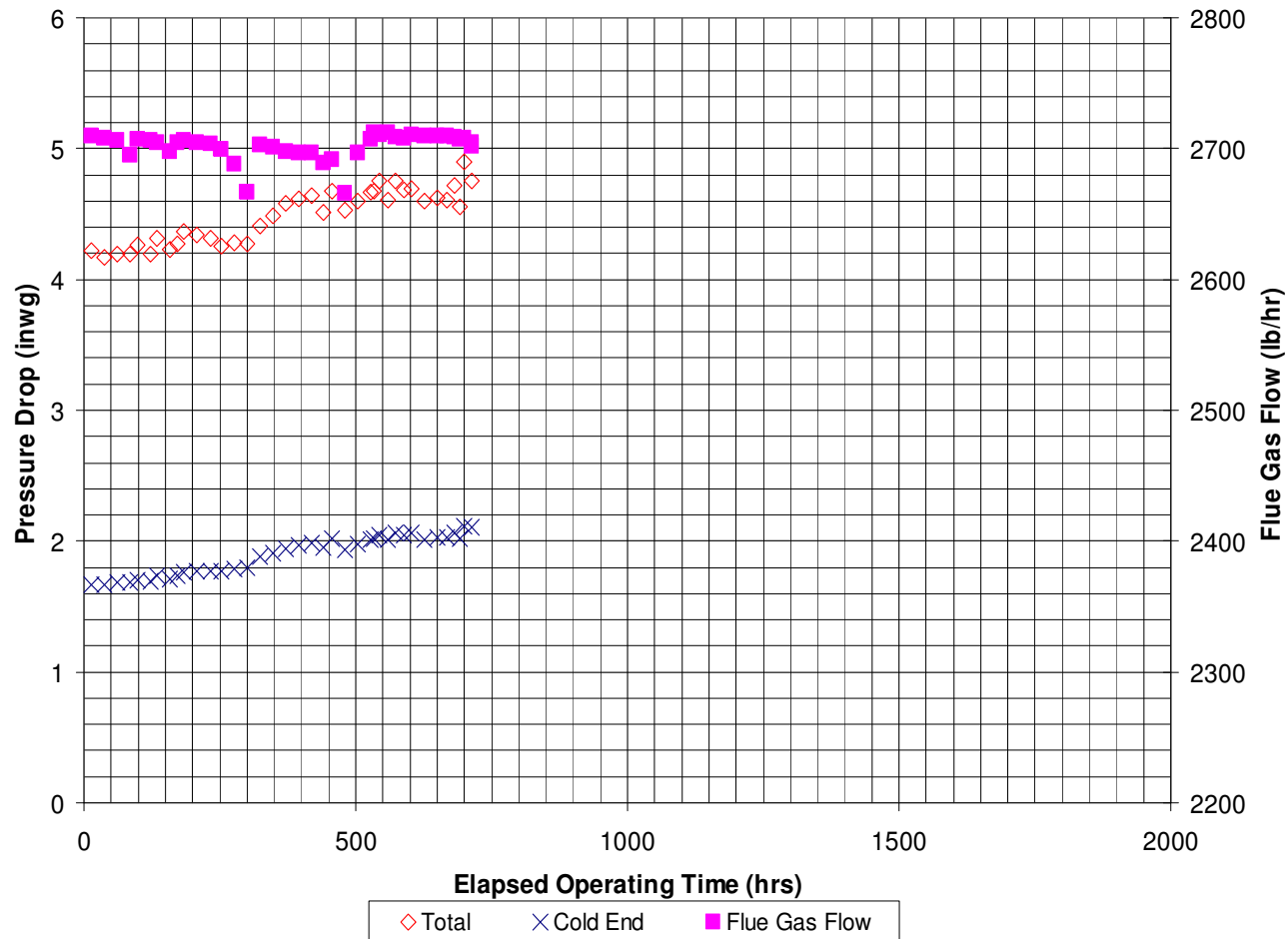


No Significant Deposit Thickness Was Found

Simulated Sodium Based SO₃ Mitigation 10ppmv SO₃ with Added Sodium Sulfate



Tower 1 Gas Side Pressure Drops



Significant Increase in Pressure Drop

Simulated Sodium Based SO₃ Mitigation 10ppmv SO₃ with Added Sodium Sulfate



Significant Sodium Bi-Sulfate Deposit at Top of Cold Layer

Conclusions from Pilot Scale Testing Simulated Sodium Based SO₃ Mitigation



- With SO₃ levels reduced to 5 ppmv ...
 - Cold layer pressure drop did not increase
 - No significant deposit thickness was found
- With SO₃ levels at 10 ppmv ...
 - Rapid increases in cold layer pressure drop occurred
 - Significant sodium bi-sulfate deposit was found
- Sodium based SO₃ mitigation must reduce SO₃ concentrations to 5 ppmv or less entering the air preheater

Background for the LGOT R&D Program

Evolution of Air Preheater Fouling Solutions

Results and Conclusions from Laboratory Testing

Plans for Full Scale Field Demonstration

Increasing Heat Recovery and Reducing Gas Outlet Temp.

- Development program includes plans for a full scale field demonstration
 - Potential demonstration site identified
 - 440 MW plant with 2 x 29.5 VI air preheaters
 - Sodium based SO₃ mitigation system in place and operating
 - Rotors already upgraded to ClearFlow™ configuration
 - Reduced exit gas temperature may be achieved by introducing a flow bias through the two air preheaters
 - Site management interested in hosting the demonstration

- Tentative schedule
 - Flow bias testing to be conducted in the fall of 2011
 - Demonstration to begin fall/winter of 2011

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Results and Conclusions from Laboratory Testing

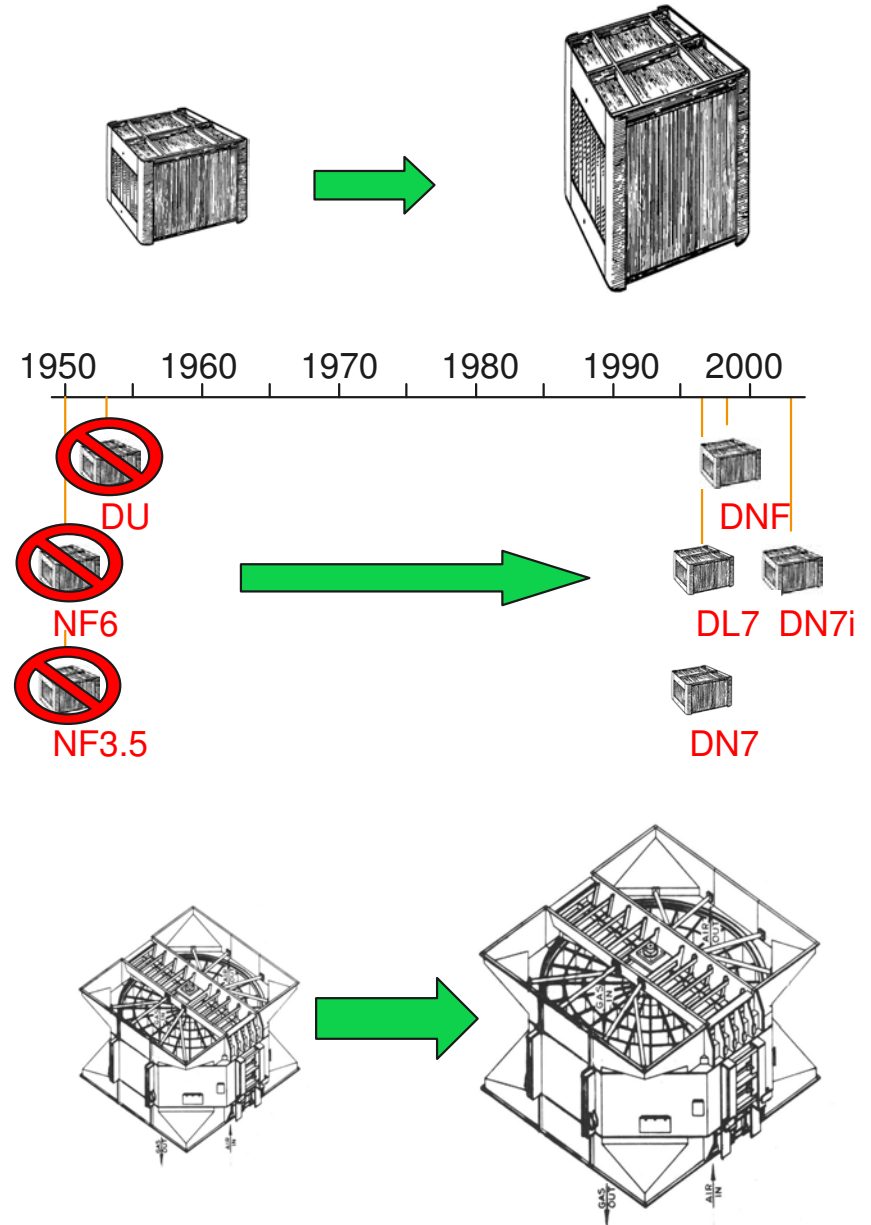
Plans for Full Scale Field Demonstration

Increasing Heat Recovery and Reducing Gas Outlet Temp.

Increasing Heat Recovery & Reducing Gas Outlet Temperature

- Add More and/or Upgrade Heat Transfer Surface

- Utilize future space
- Low profile baskets
- Higher efficiency element
- Rotor upgrade
- Larger air preheater



Increasing Heat Recovery & Reducing Gas Outlet Temperature

- Eventually the thermodynamic limit will be reached

Gas Side Effectiveness

$$= \eta_{\text{gas}} = (T_{\text{gi}} - T_{\text{goNL}}) / (T_{\text{gi}} - T_{\text{ai}})$$

Air Side Effectiveness

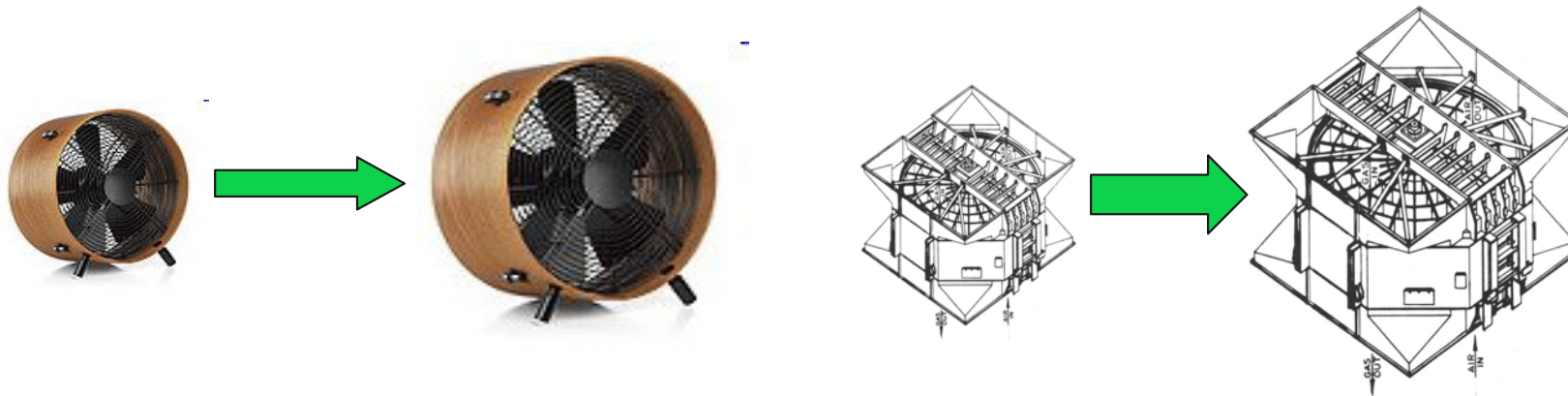
$$= \eta_{\text{air}} = (T_{\text{ao}} - T_{\text{ai}}) / (T_{\text{gi}} - T_{\text{ai}})$$

$$\text{X-Ratio} = X_R = (W_{\text{ao}} c_{\text{pair}}) / (W_{\text{gi}} c_{\text{pgas}})$$

$$\text{or, } X_R = (T_{\text{gi}} - T_{\text{go}}) / (T_{\text{ao}} - T_{\text{ai}})$$

$$\text{or, } X_R = \eta_{\text{gas}} / \eta_{\text{air}}$$

- Further gains may be obtained by increasing total air flow
 - How can the additional hot air be used to raise plant efficiency?



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