AN INTEGRATED APPROACH TO PREDICTING ASH DEPOSITION AND HEAT TRANSFER IN COAL-FIRED BOILERS

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May 12th, 2022

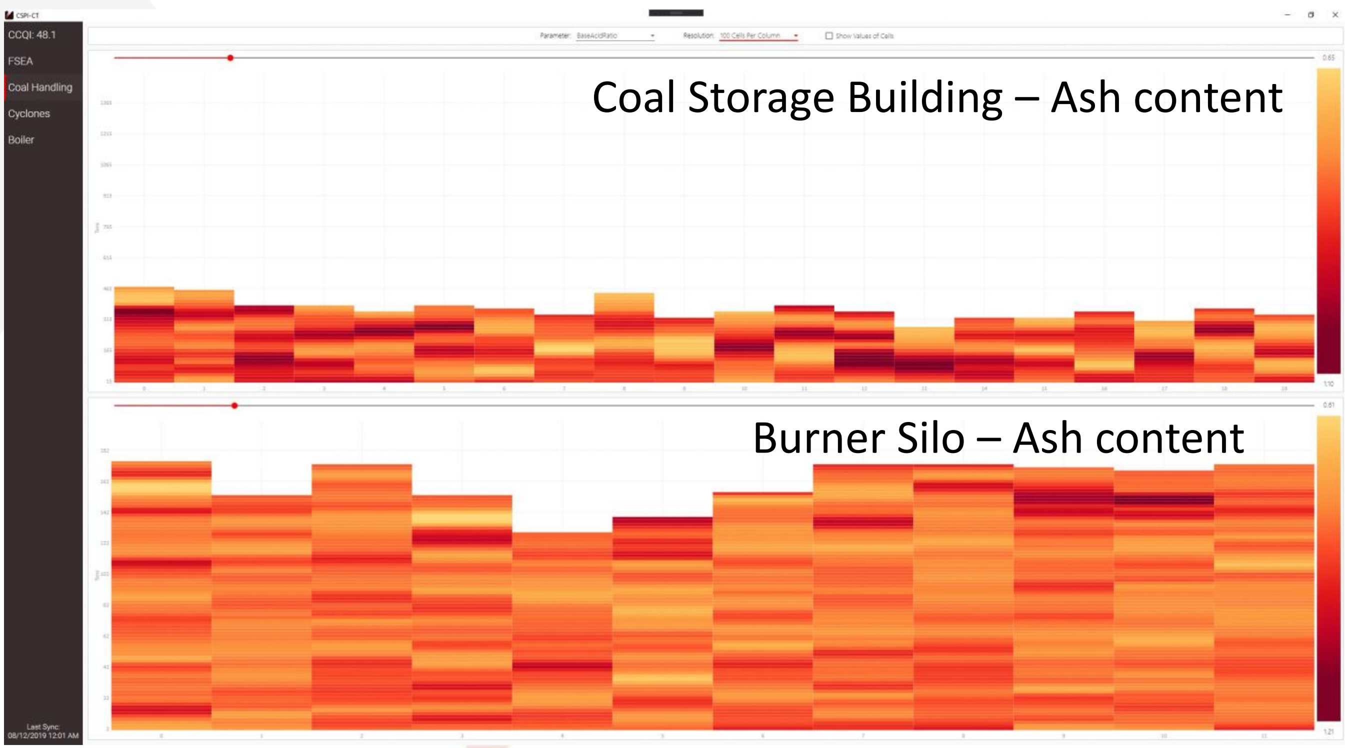
DOE FE R&D Project Review Meeting

University Coal Research

Acknowledgement: This research is being funded by the University Coal Research Program which is administered by DOE-NETL (Award #: DE-FE0031741)

Objectives

Advance **on-line** technology to **predict**, **monitor** and **manage** fireside ash deposition allowing for more efficient operations under a range of **load** conditions and **fuel property** variability



Management Strategy

- Fuel sorting and blending can be done upstream
- Optimize operations to compensate for load and fuel properties
- Optimized composition of coal delivered to each burner

Output Screen from CSPI-CT
Microbeam's Existing on-line Technology

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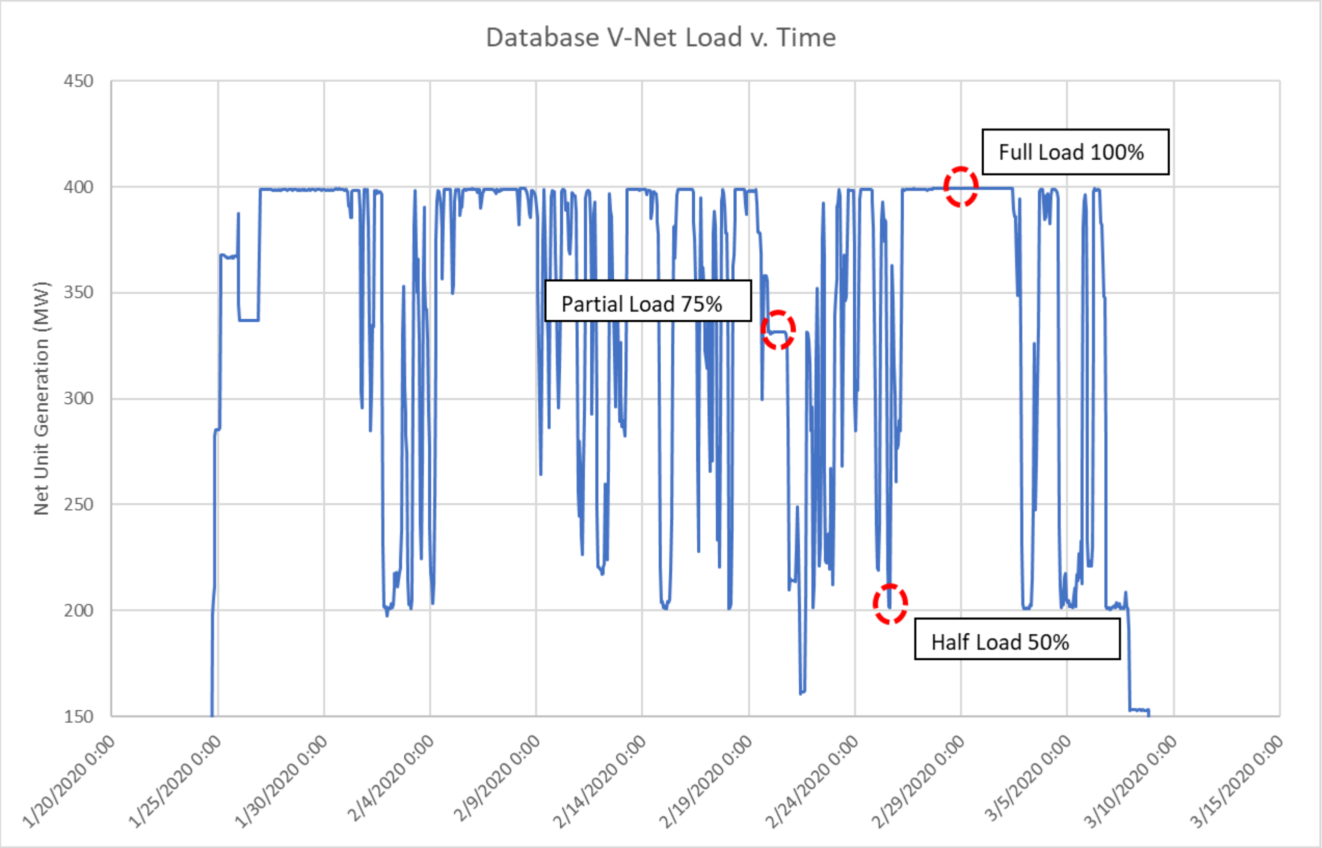
Load Definition Selection



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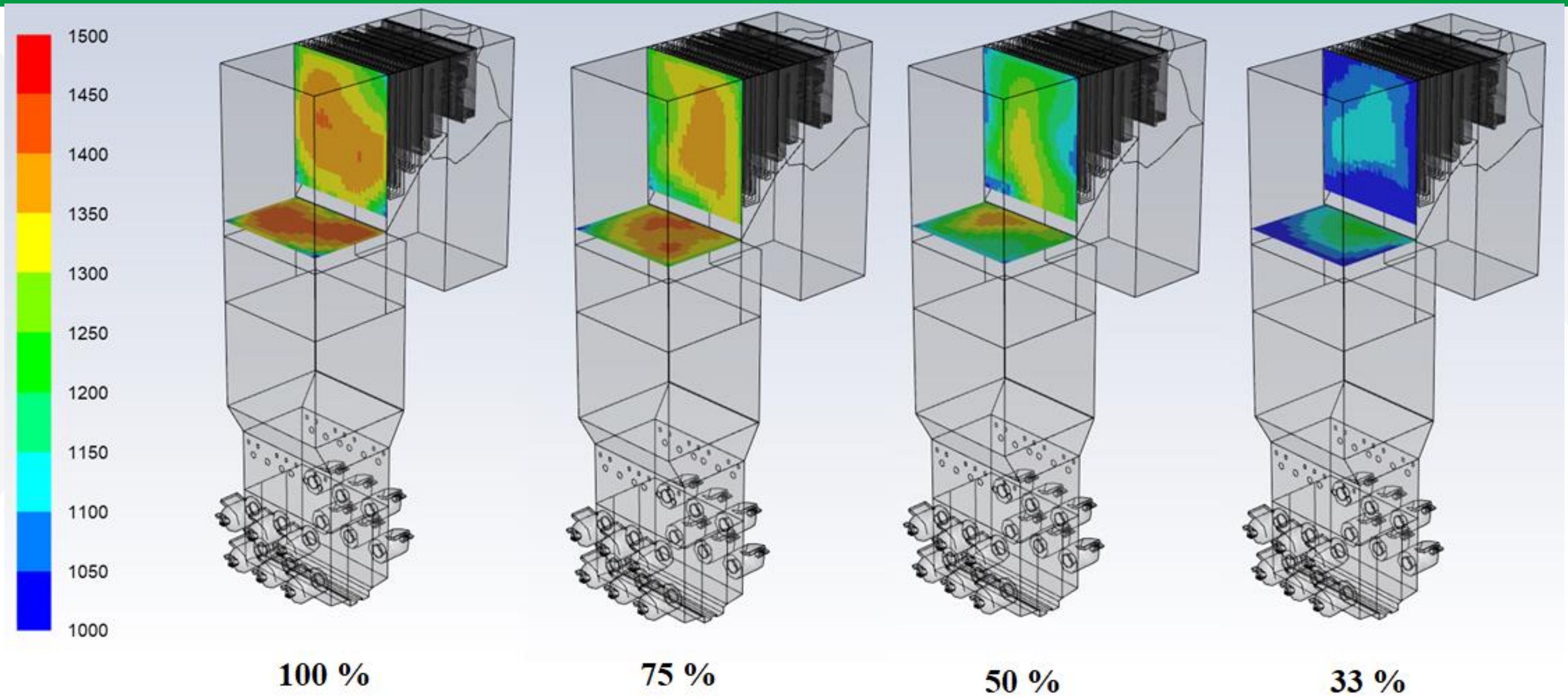
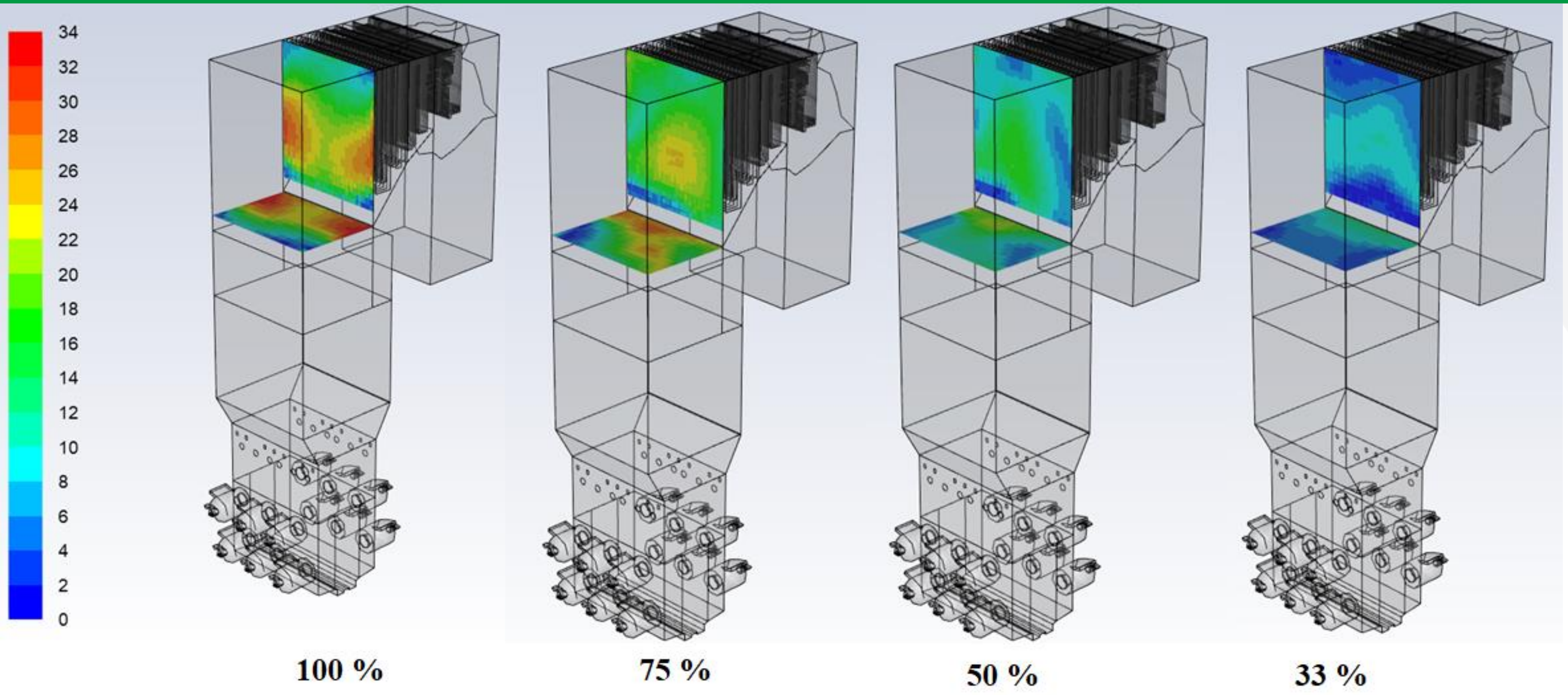
Temperature (in K)



Velocity (in m/s)



Impaction and Capture Efficiencies

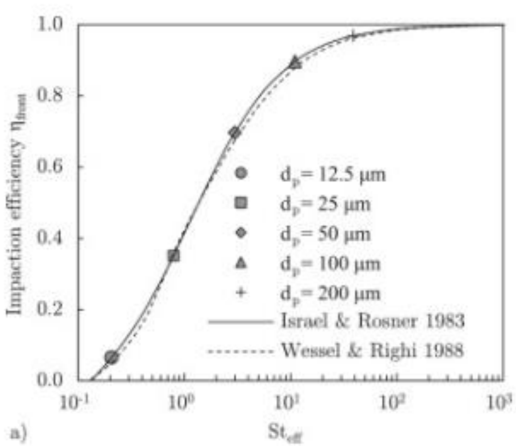
Ash deposition is a function of:

Impaction efficiency (Particle Stokes number)

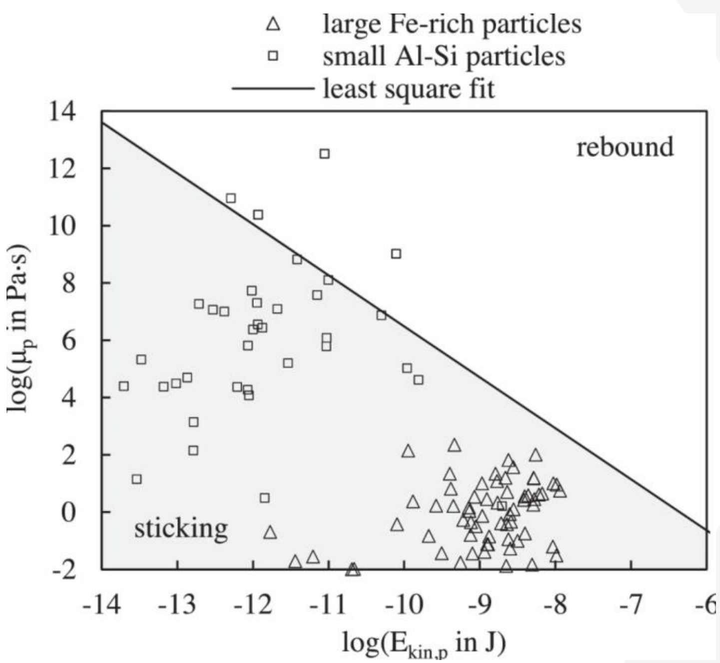
- Particle size distribution
- ✓ Gas velocity
- ✓ Gas viscosity

Capture Efficiency

- Particle viscosity (temperature and composition)
- Particle KE (particle size distribution and velocity)



flue gas velocity of $u_\infty = 10$ m/s and a gas temperature of $T_g = 1000$°C.



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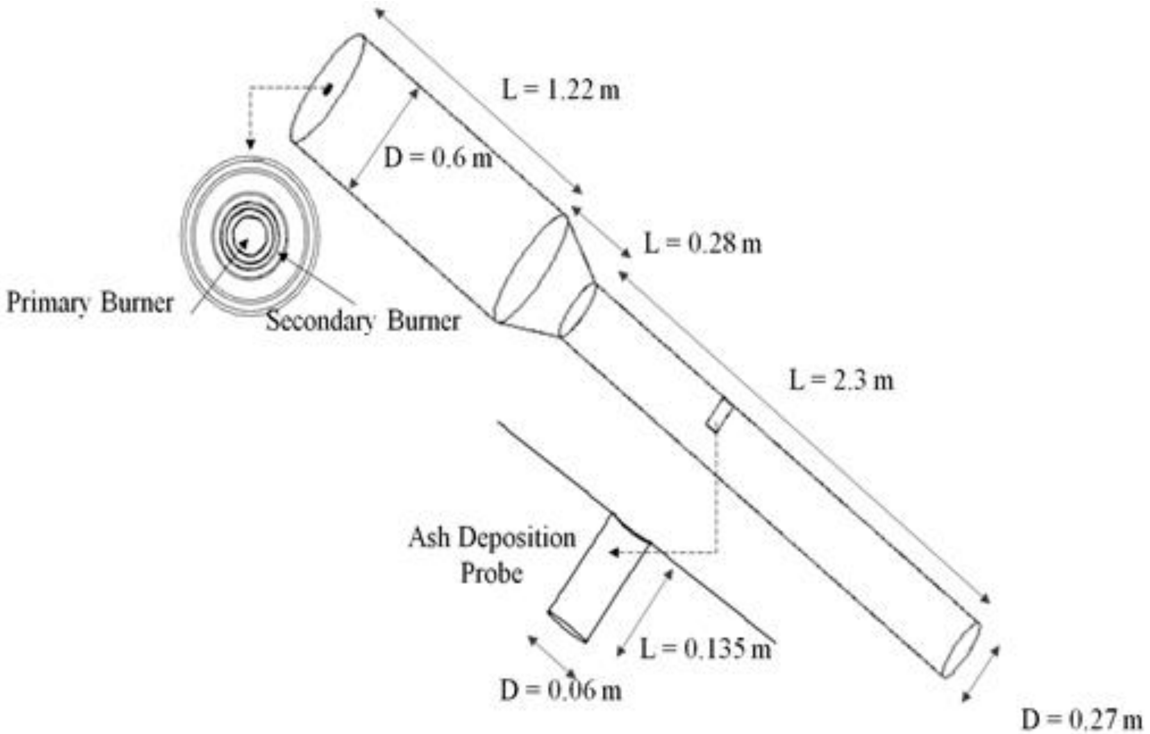
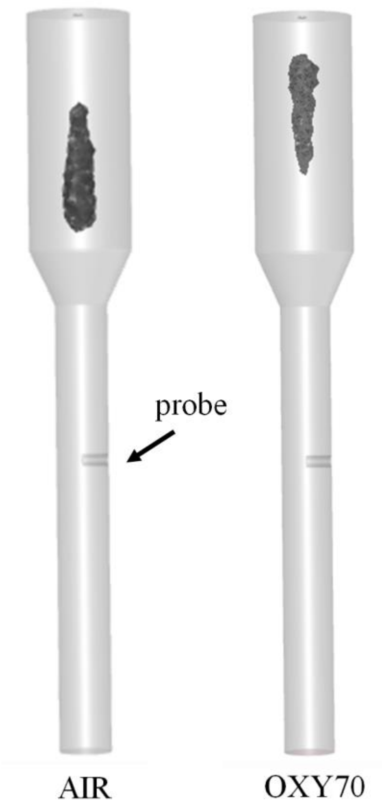
Methodology validation against well characterized lab-scale measurements





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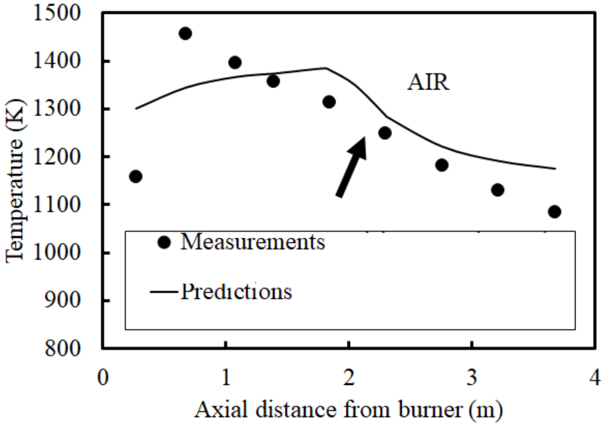

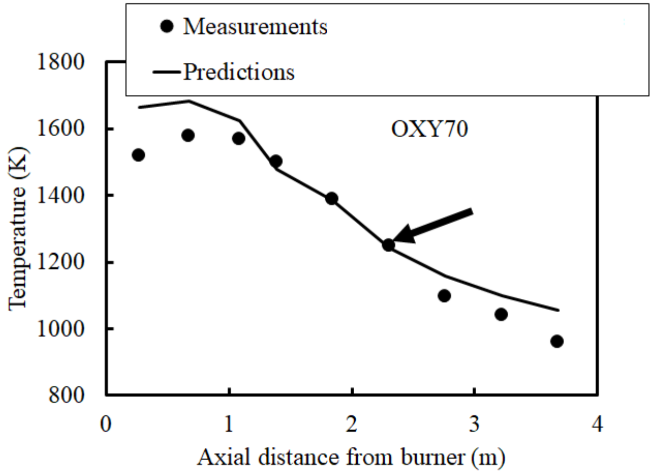

	Measured	Predicted
AIR (g/m^2-hr)	257	226
OXY70 (g/m^2-hr)	569 +/- 38	701
Deposition rate enhancement (OXY70/AIR)	2.1 – 2.4	3.1

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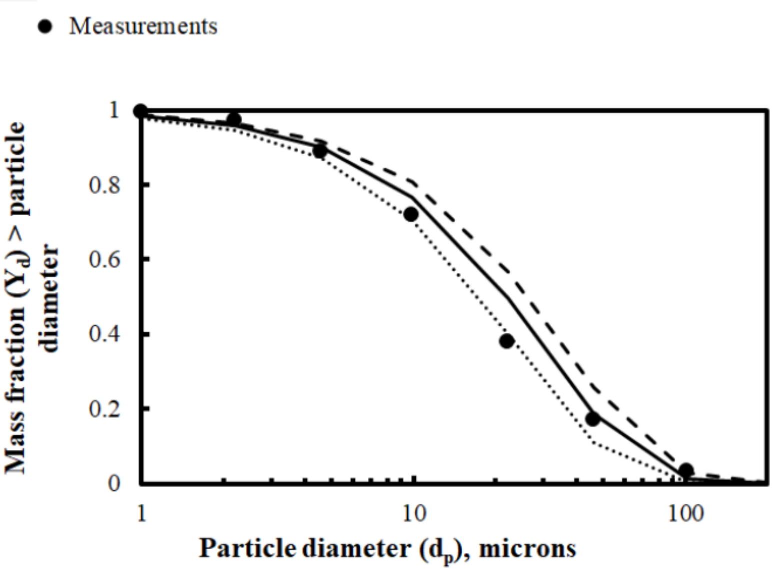
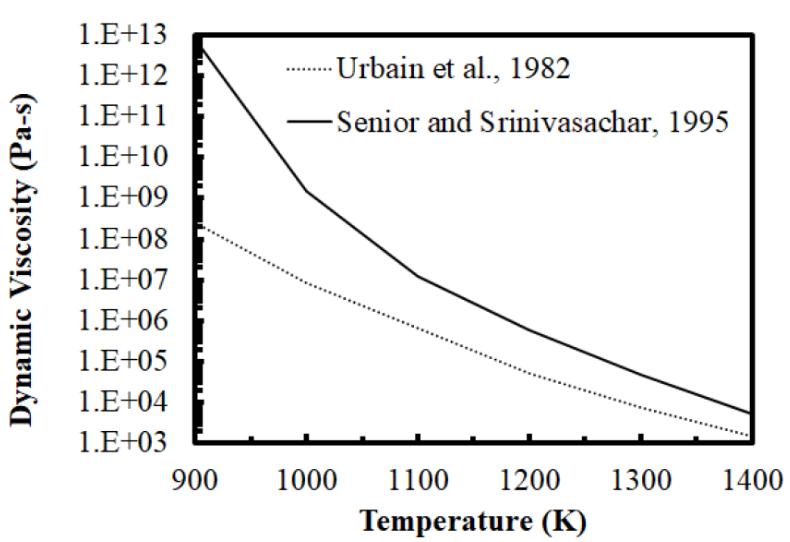
Ensure methodology robustness with modeling uncertainties





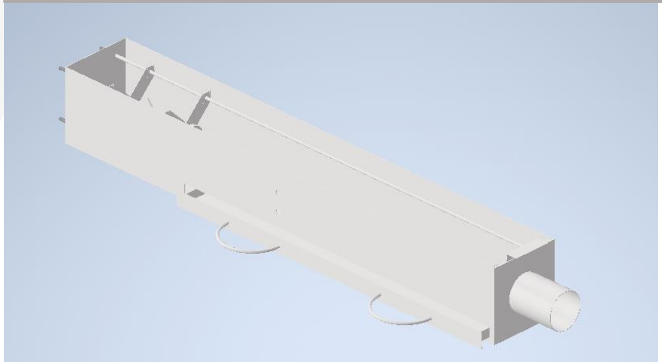
Predicted deposition rate enhancement: 2.8 to 3.7
Measured deposition rate enhancement: 2.1 to 2.4

Microbeam's Gas-Side Deposit Probe Geometry

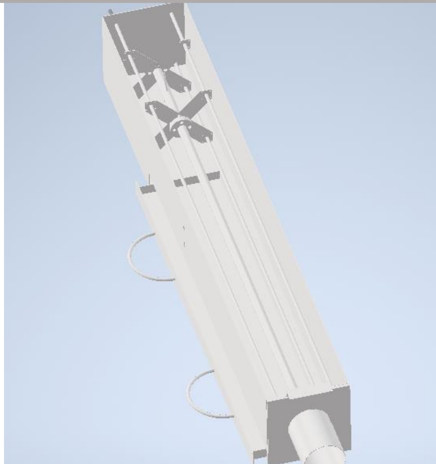
Microbeam's gas-side fouling deposit probe is used to collect ash deposits from coal-fired boilers.

The probe was successfully used to collect and extract ash deposits from a boiler during operation.

CAD models of the initial deposit probe design a) side view and b) top view.

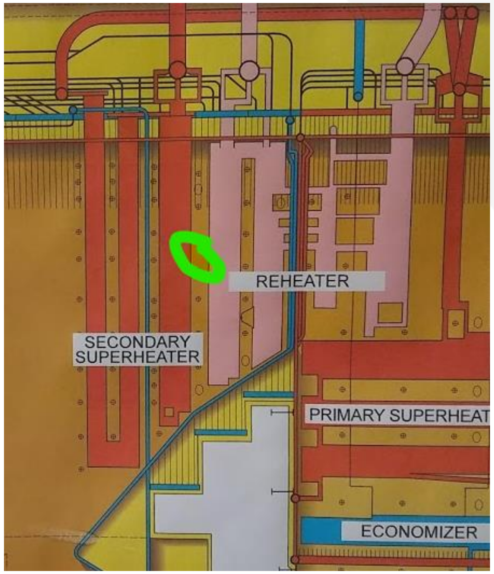


a) side view



b) top view

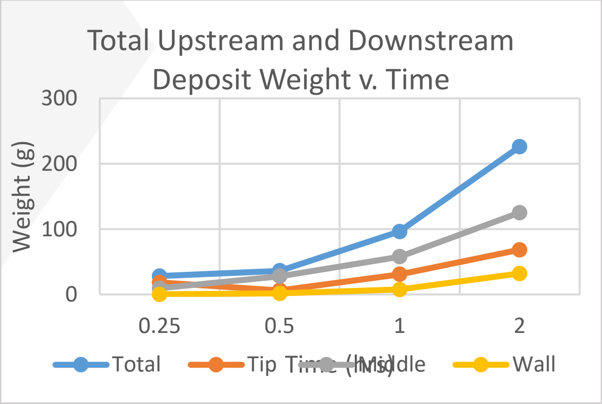
The probe is a 5 ft long, 1" T22 steel tube on which deposits develop.

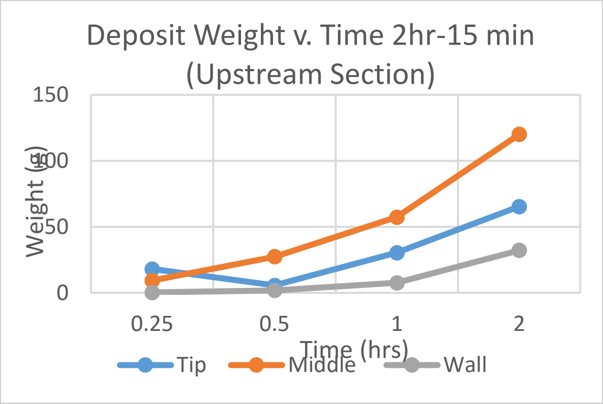


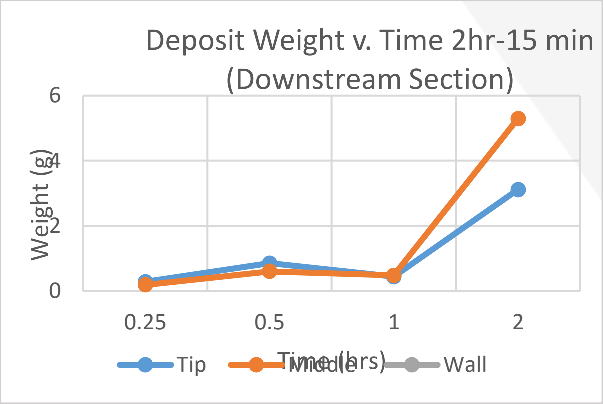
The probe was inserted horizontally through a port in the boiler between the secondary superheater and reheater heat exchange sections (gas temperature roughly 1600 °F).

Deposition Rates During the Field Test – Full Load Conditions

Information gathered from the deposition probe was used to determine deposit growth rates and collect ash deposits for characterization to determine the processes involved in the formation of ash deposits.







The objective of the field test was to successfully extract ash deposits from a boiler during operation to gather information on deposit sample weight over time. The weights of collect deposits were then charted and compared (Day 4 results are shown above as examples).

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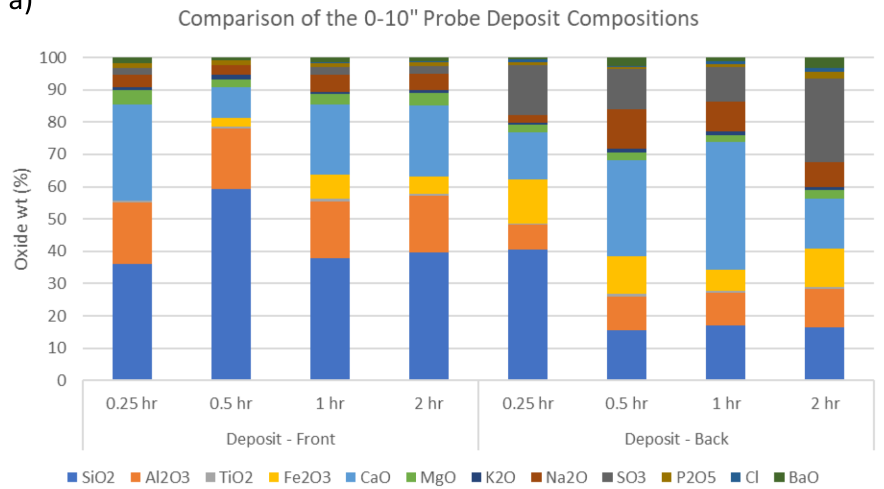
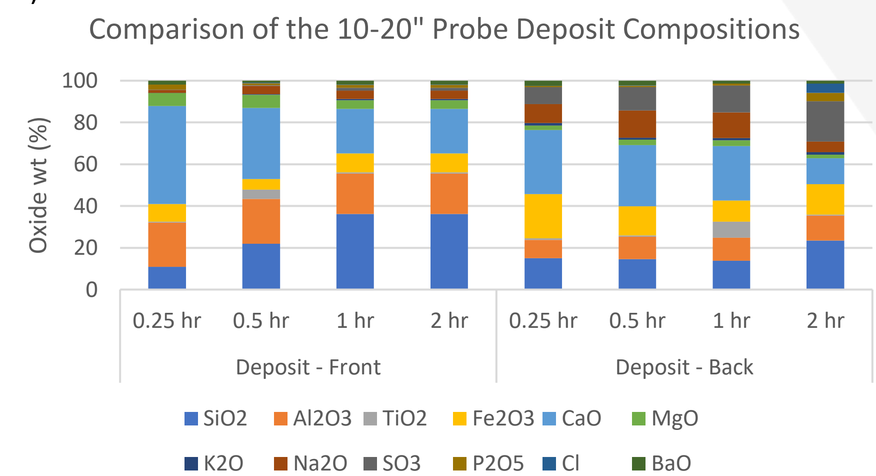
Deposit Composition Variation

Deposit samples were collected from varying positions at the front and back sections of the ash deposition probe.

a)



b)



Major oxide ash composition (%) for the upstream and downstream a) 0-10” probe deposit samples and b) 10-20” probe deposit samples.

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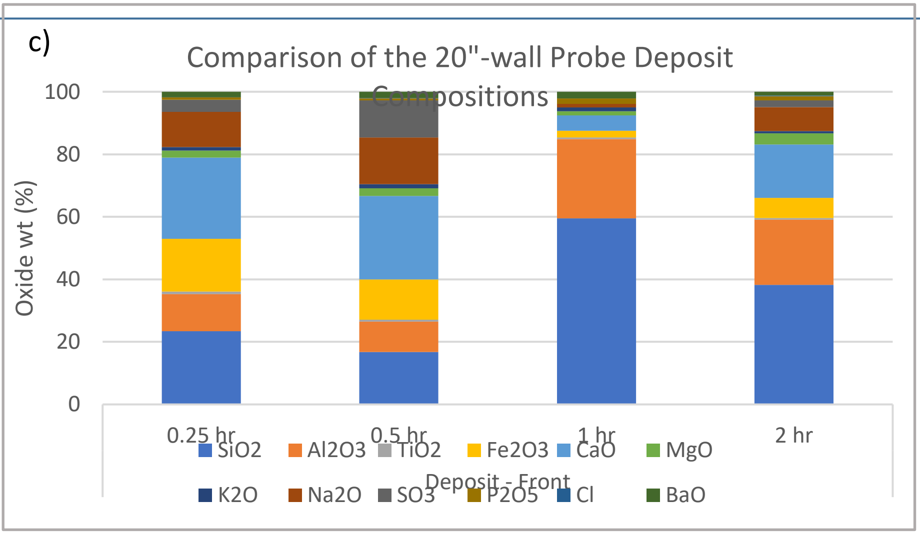
Deposit Composition Variation (continued)

Deposit samples were collected from varying positions at the front and back sections of the ash deposition probe.



Major oxide ash composition (%) for the upstream and downstream c) 20” - wall probe deposit samples.

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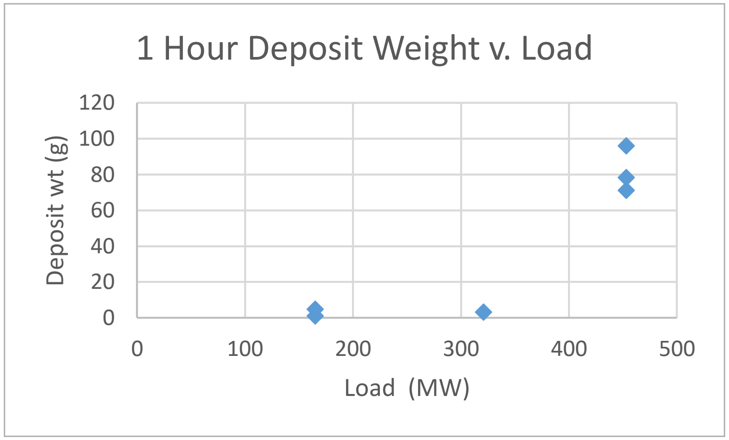
Deposition Rates During the Field Test – Reduced Load Conditions

Information gathered from the deposition probe was used to determine deposit growth rates and collect ash deposits for characterization to determine the processes involved in the formation of ash deposits.



Low load conditions decrease temperature and creates a growth and shedding process.

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Milestones completed

Milestone	Task/ Subtask	Milestone Title and Description	Planned Completion Date	Verification Method
1	Task 1	Project Management Planning	8/31/2019	PMP Updated
2	Task 1	Project Kick-off Meeting	10/31/19	Project kick-off meeting conducted
3	Task 2	Combustion simulations within cyclone barrels	1/31/2020	Completion of simulations within cyclone barrels encompassing 12 representative operational scenarios
4	Task 2	Combustion simulations within a full-scale boiler employing the results from the cyclone barrel simulations	7/31/2020	Completion of simulations encompassing 12 representative operational scenarios
5	Task 3	Thermal modeling refinement with validation against data from plant	7/31/2021	Thermal modeling refinement and validation of the simulations encompassing the 12 representative scenarios selected in Task 2
6	Task 3	Deposition modeling refinement with validation against data from plant	1/31/2022	Deposition modeling refinement and validation of the simulations encompassing the 12 representative scenarios selected in Task 2
7	Task 4	CSPI-CT Tool Refinement	7/31/2022	Functional/parametric relationships relating to plant performance are developed and/refined
8	Task 4	Installation, testing and performance assessment of the CSPI-CT tool	7/31/2022	The CFD augmented CSPI-CT tool is installed on site and its performance is assessed

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Take-Home Message(s)

<u>Predicting ash deposition</u>: This is almost as complicated as it gets…

- Its important to have high-fidelities in:
  - Ash PSD
  - Gas velocities
  - Particle/gas temperature
  - Ash composition
- First, focus on getting the impaction rates right! (highly resolved grids)
- Next, validate capture methodology against well resolved lab-scale measurements and access input parameter uncertainties
- Extend the methodology to larger scales (where measurements may not be available and uncertainties are greater)
- <u>Close interactions between</u>: boiler personnel, coal quality experts and CFD practitioners are necessary at all levels

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Acknowledgements

- This research is being funded by the University Coal Research Program which is administered by DOE-NETL (Award #: DE-FE0031741) (1 student + 1 Post-Doc supported on the project)
- Otter Tail Power Company – Providing data on fuel properties and plant operations.

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Questions?