Flow Modeling for Popcorn Ash Capture

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Popcorn Ash Formation & Capture

Small particles exit the burners; how do they get so big?

- Combustion plays a key role
  - FEGT
  - Burner, OFA, and furnace flow patterns
- Agglomeration of soft ash particles in the upper furnace
  - Particle collisions during flight
  - Tumbling in flow recirculation regions
  - Build up on tube surfaces; re-entrainment during soot blowing or by gas stream
  - Assuming you cannot avoid popcorn ash exiting the boiler, capturing it *before* it gets to the SCR is the only option
  - Engineering design procedure includes some, if not all, of **(i) field testing, (ii) lab analysis, (iii) flow modeling**

Popcorn Ash Characteristics

Several features of popcorn ash make it difficult (but not impossible) to predict its behavior in a gas stream

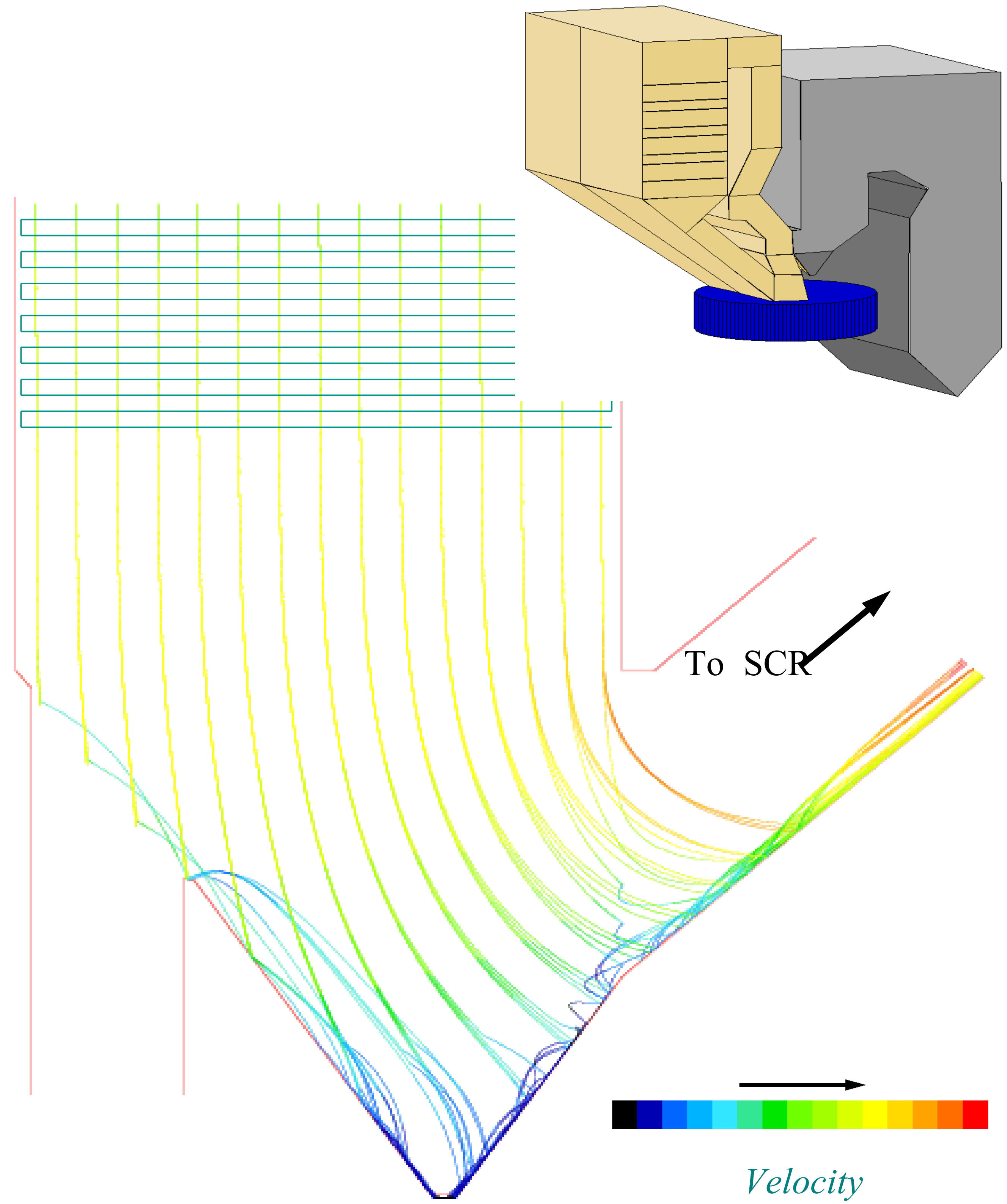
- Light weight (Specific gravity <1.0)
  - Difficult to capture by mechanical separation
- Irregularly shaped
  - Unique drag coefficient
  - Random rebound behavior
- Determined by Lab Analysis
  - Size distribution
  - Specific gravity
  - Drag coefficient
  - Rebound characteristics

Field Testing

- Performed upstream and downstream of the economizer hopper
- Tests performed include
  - Velocity traverse
    - Flow distribution
    - Integrated mass flow rate
    - Temperature distribution
  - Isokinetic ash sampling
    - Ash flow rate
    - Size distribution
    - Provide samples for lab analysis
- Baseline testing
- Post-installation testing

Flow Modeling

- Computational Fluid Dynamics (CFD) model of economizer hopper region
- Model used to predict
  - Velocity patterns
  - Ash particle trajectories
  - Capture efficiency of economizer hopper
  - Pressure loss
  - Erosion potential
- Track ash particles through the economizer hopper region
- Calculate hopper capture efficiency for various particle sizes
- Use model to evaluate wide range of design options

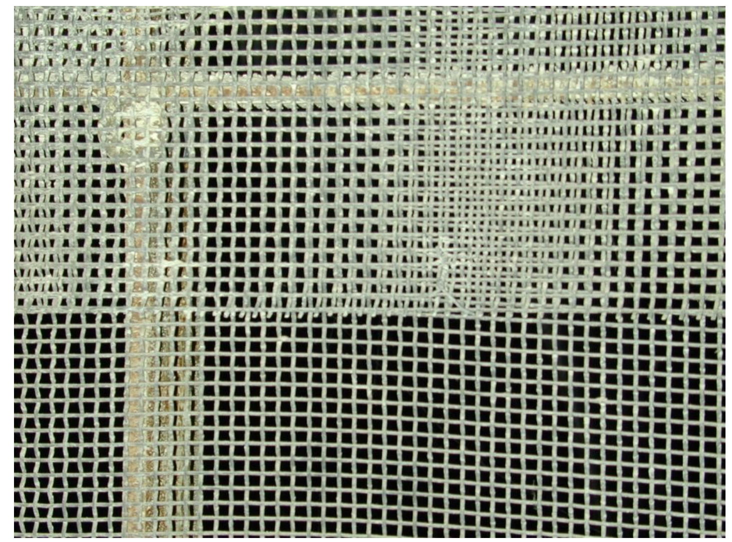


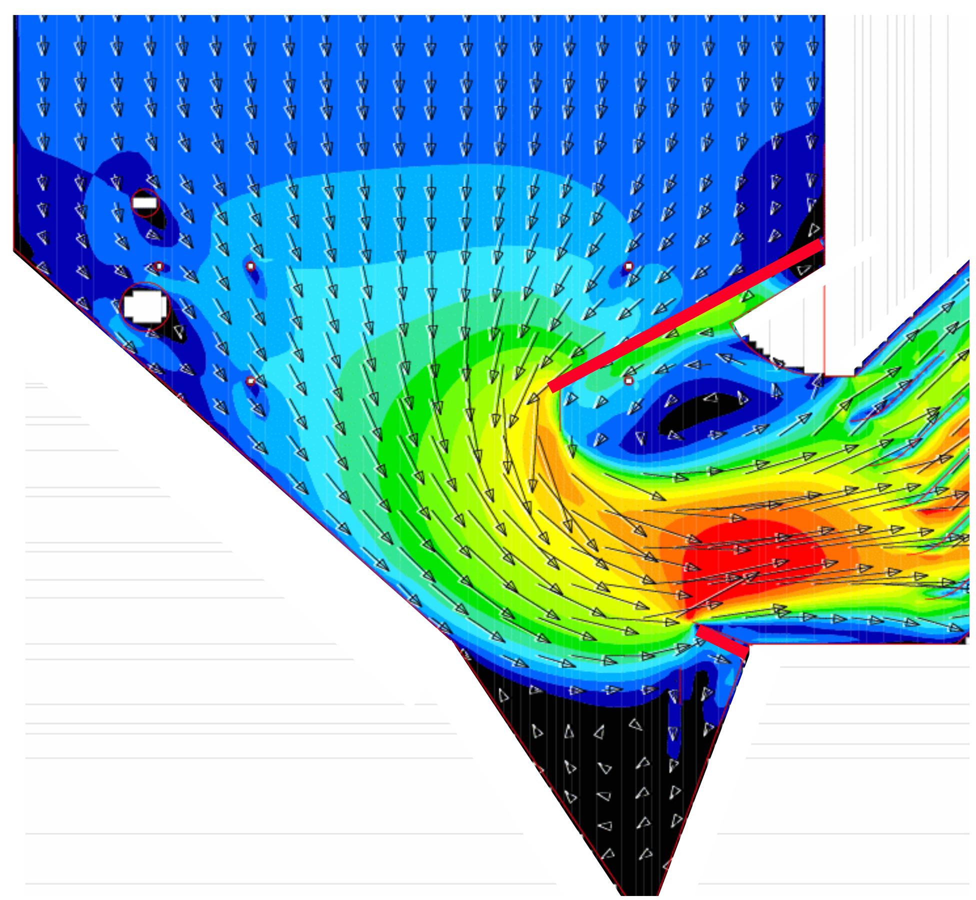
Baseline Geometry

1 mm particle streamlines - 60% capture

Economizer Hopper Modifications

- Aerodynamic baffles
  - Mechanically separate large ash particles; send them to the hopper
  - Baffles located above and within the economizer hoppers
  - Pro
    - Consistent capture over time
    - Consistent DP over time
  - Con
    - Pressure loss (up to 2 IWC)
    - Performance dependent on hopper region geometry
    - Potential erosion of downstream structure, instrumentation (O_2 probes)





- Screens
  - Filter out large particles using wire mesh
  - Locate in inlet ductwork or at SCR inlet face
  - Pro
    - Design for specific size capture
    - Lower DP than baffles (<1 IWC)
  - Con
    - Inconsistent DP due to pluggage over time
    - Inconsistent capture efficiency due to erosion
    - Maintenance required to clean and repair

Case Study

- Southeastern utility
  - ~700 MW tangentially fired unit
  - Screen at economizer outlet replaced every 6 months
- CFD modeling performed
  - Baseline: 78% of 5 mm particles captured
  - With baffles: 100% of 5 mm particles captured
- Baffles installed with SCR spring 2004
  - Screen retained
- Inspection occurred fall 2004
  - Screen totally eroded
  - Negligible quantity of popcorn ash on catalyst
  - Estimated 99.9998% popcorn ash captured in economizer hoppers
  - Attributed to presence of baffles