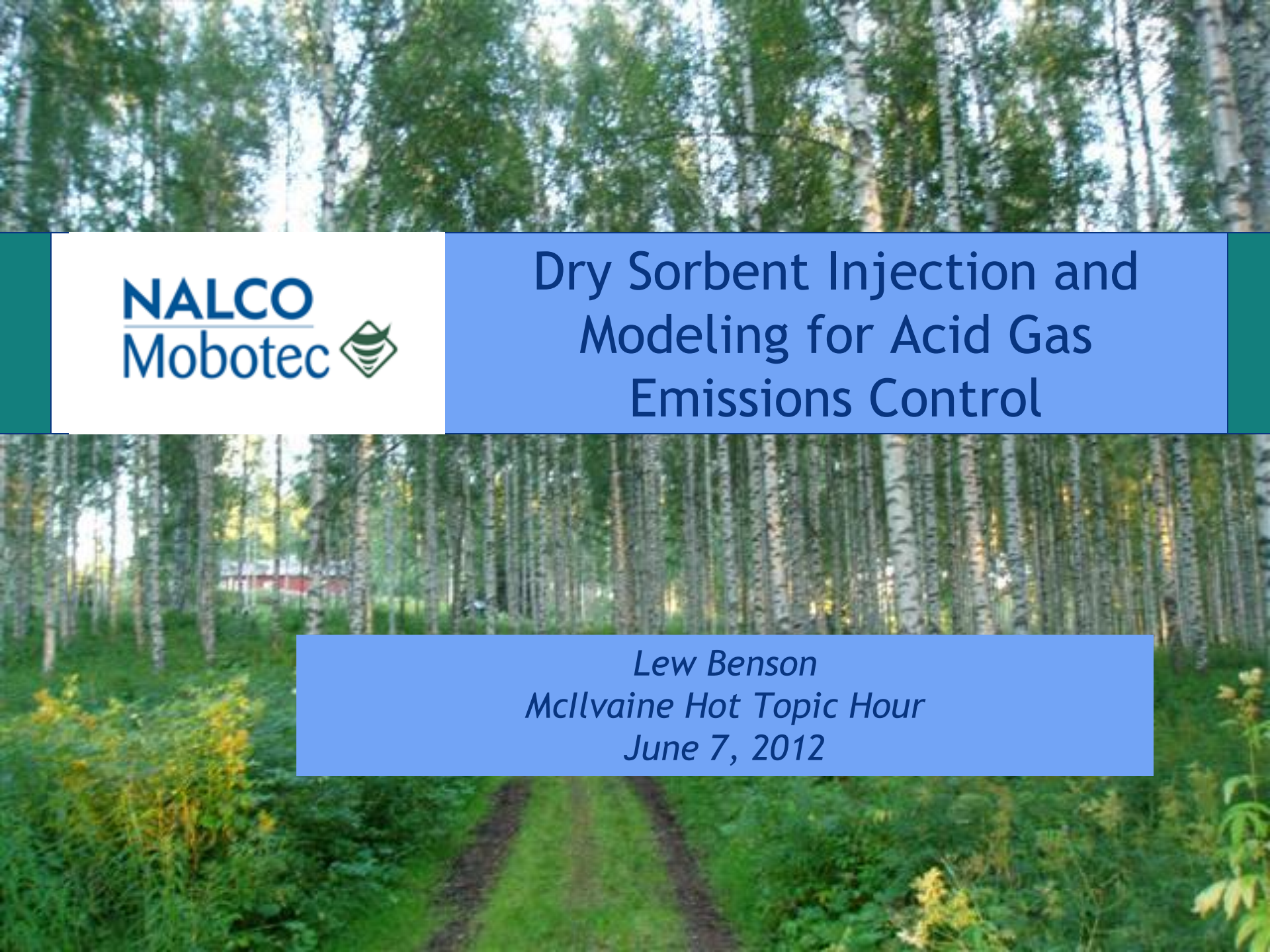

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Dry Sorbent Injection and Modeling for Acid Gas Emissions Control

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McIlvaine Hot Topic Hour

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Overview of Presentation

- Background on dry sorbent injection (DSI) at electric generating plants
- Why DSI for acid gas control?
- Types of DSI applications for SO_2, SO_3, HCl control
- Nalco Mobotec capabilities for DSI projects
- Usefulness and necessity of CFD and pollutant capture modeling

Background on DSI for Acid Gas Control

- DSI for SO_2 control at electric generating plants
  - Furnace sorbent injection (FSI) and sodium injection full-scale demonstration in early 1990's
  - 1100 MW recent DSI installations using sodium sorbent with sub-bituminous coal
- DSI for SO_3/H_2SO_4/sulfuric acid mist control since 2001
  - Since 2001, >25,000 MW total at U.S. utilities for visible plume abatement
    - 22 generating units using trona
    - >34 units using hydrated lime
    - Utility users groups available
- DSI for HCl control for MATS/MACT
  - Numerous evaluations and full-scale trials conducted and planned

Why Dry Sorbent Injection (DSI)?

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- Retrofit control of SO_3/H_2SO_4/SAM, SO_2, HCl
- Low equipment cost solution for acid gas control
  - Much lower in equipment cost compared with conventional acid gas control (semi-dry and wet FGD)
    - Examples: SO_3 control typically <$5/kW
- "Bridge" SO_2 control for older units burning low-sulfur fuel, especially sub-bituminous coal
  - Much lower equipment cost than semi-dry FGD, higher sorbent cost
- Fast project schedule, typically 12 months
- Expect minor modifications to furnace or flue gas ductwork, ash handling

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Why DSI?

- SO_2 control when <80% reduction required
  - To meet SO_2 allocation limit of Cross-State Air Pollution Rule (CSAPR)
- SO_3/H_2SO_4/sulfuric acid mist (SAM) control
  - Prevent visual opacity violations due to H_2SO_4 mist
  - Avoid exceeding PSD limit for H_2SO_4/SAM
  - Reduce filterable and condensable particulate emissions due to H_2SO_4
- HCl control
  - Compliance w/proposed Utility MACT and industrial boiler MACT rules for existing units
- Simultaneous SO_2 and HCl control to meet both CSAPR and MACT
  - Good fit for units burning sub-bituminous coal with low chlorine content

Why DSI?

- Uses widely available commercial sorbents
  - Pulverized limestone
  - Hydrated lime
  - Sodium-based sorbents: trona, sodium bicarbonate
- Relatively easy to conduct full-scale demonstrations at individual generating units

DSI Applications for SO2, SO3, HCl Control at Electric Generating Units

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- Furnace sorbent injection of limestone or hydrated lime for SO2 control
  - 1300 MW Nalco Mobotec references
- Post-economizer injection of trona or sodium bicarbonate for SO2 control
- Pre-ESP or baghouse injection of trona/sodium bicarbonate for SO2 control
- Pre-ESP or baghouse injection of hydrated lime for SO3 control
- Pre-ESP or baghouse injection of trona/sodium bicarbonate or hydrated lime for HCl control
- Pre-wet FGD injection of hydrated lime for SO3 control

DSI System for SO_3 Control

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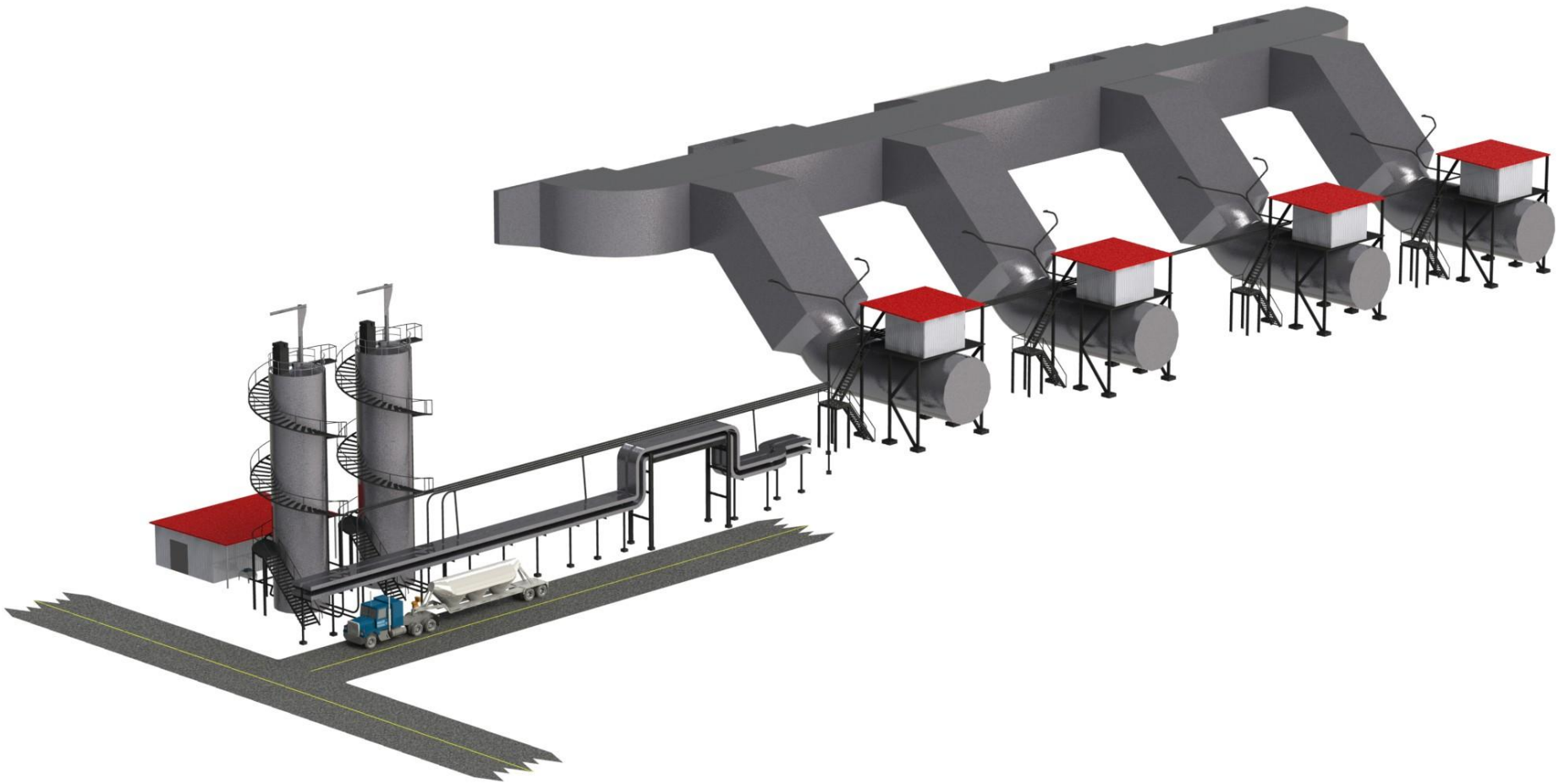

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Nalco Mobotec DSI Capabilities

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- Application evaluation
  - Choice of sorbent and injection location, review of existing performance data, potential interferences with mercury capture, need for injection trial, preliminary CFD modeling
- Conduct of full-scale injection trials
  - Industrial scale: up to 1000 lb/hr
  - Utility scale: up to 12000 lb/hr
- CFD and mass transfer/chemical kinetic modeling
- Process engineering and performance guarantees
- Specification of DSI equipment
  - Trona/sodium bicarbonate mill selection
  - Equipment typically pre-assembled for easiest installation
- Installation supervision
- Commissioning

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CFD and Mass Transfer/Chemical Reaction Kinetics Experience and Capability

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- In-house CFD modeling group – 6 PhD's
- Furnace combustion modeling - >10 years experience
  - Originally to support ROFA® NOx control system design
- Furnace sorbent injection modeling for SO_2 capture
  - Simultaneously accounts for sorbent dispersion, calcination, sintering, mass transfer, reaction kinetics
- Duct sorbent injection modeling for SO_2, SO_3, HCl capture
  - Dispersion only
  - Dispersion and mass transfer and reaction kinetics
    - SO_3 capture with hydrated lime
  - Dispersion, calcination, sintering, mass transfer, reaction kinetics
    - Acid gas capture with trona/sodium bicarbonate - under development

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Usefulness of Pollutant Capture Modeling

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- Design only for %RMS dispersion is incomplete
- Supports plan and conduct of sorbent injection trials
  - Design trial to confirm expected performance correlations
  - Confirm results make sense while trial is underway
  - Account for changes in inlet pollutant conc., sorbent-gas contact time, etc.
- Use when injection trial not possible
  - E.g., SO_3 control following SCR installation
- Provide more useful CFD modeling for lance design and location
- Provide systematic basis for sorbent injection rate for specifications and technology evaluations

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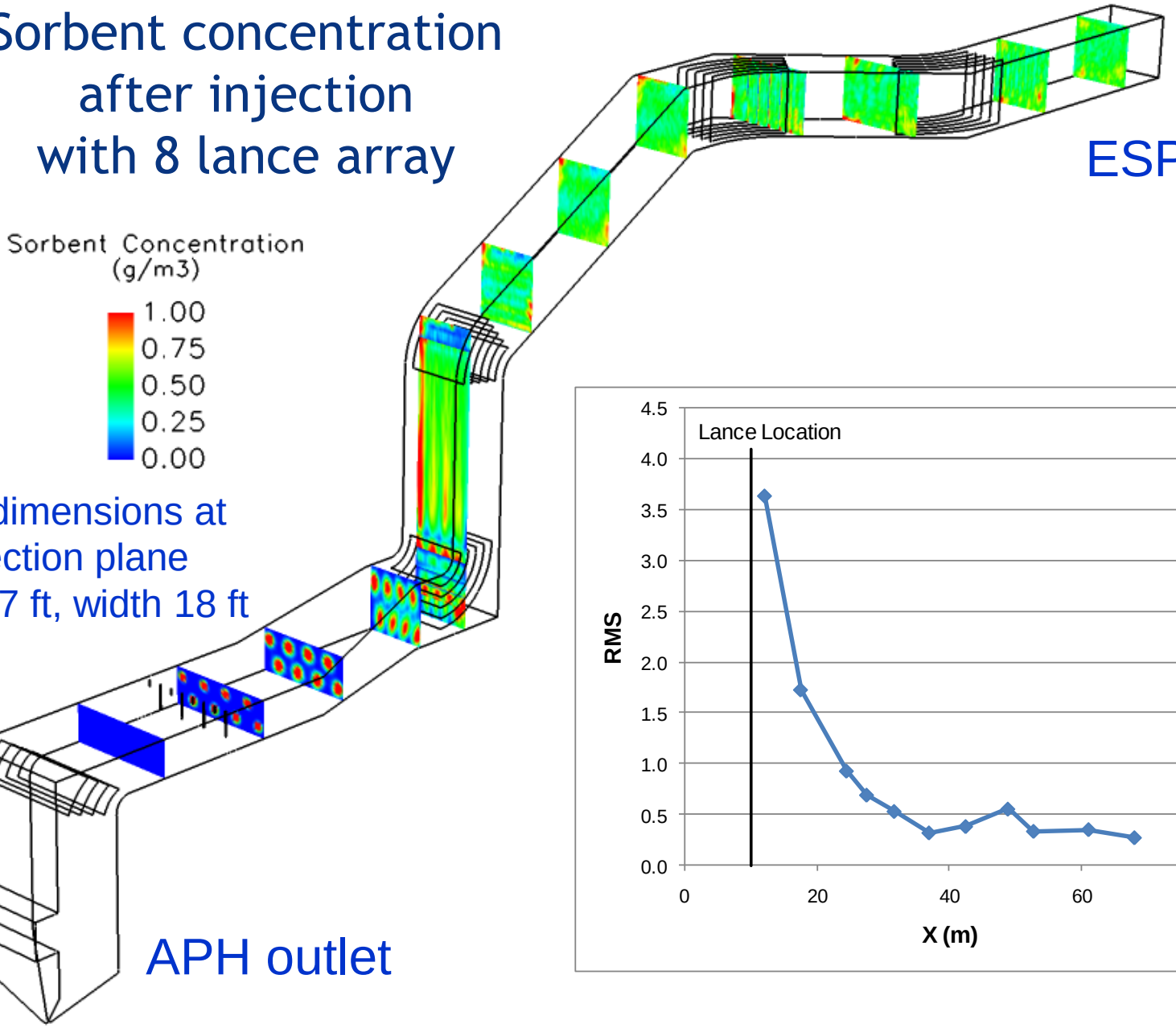
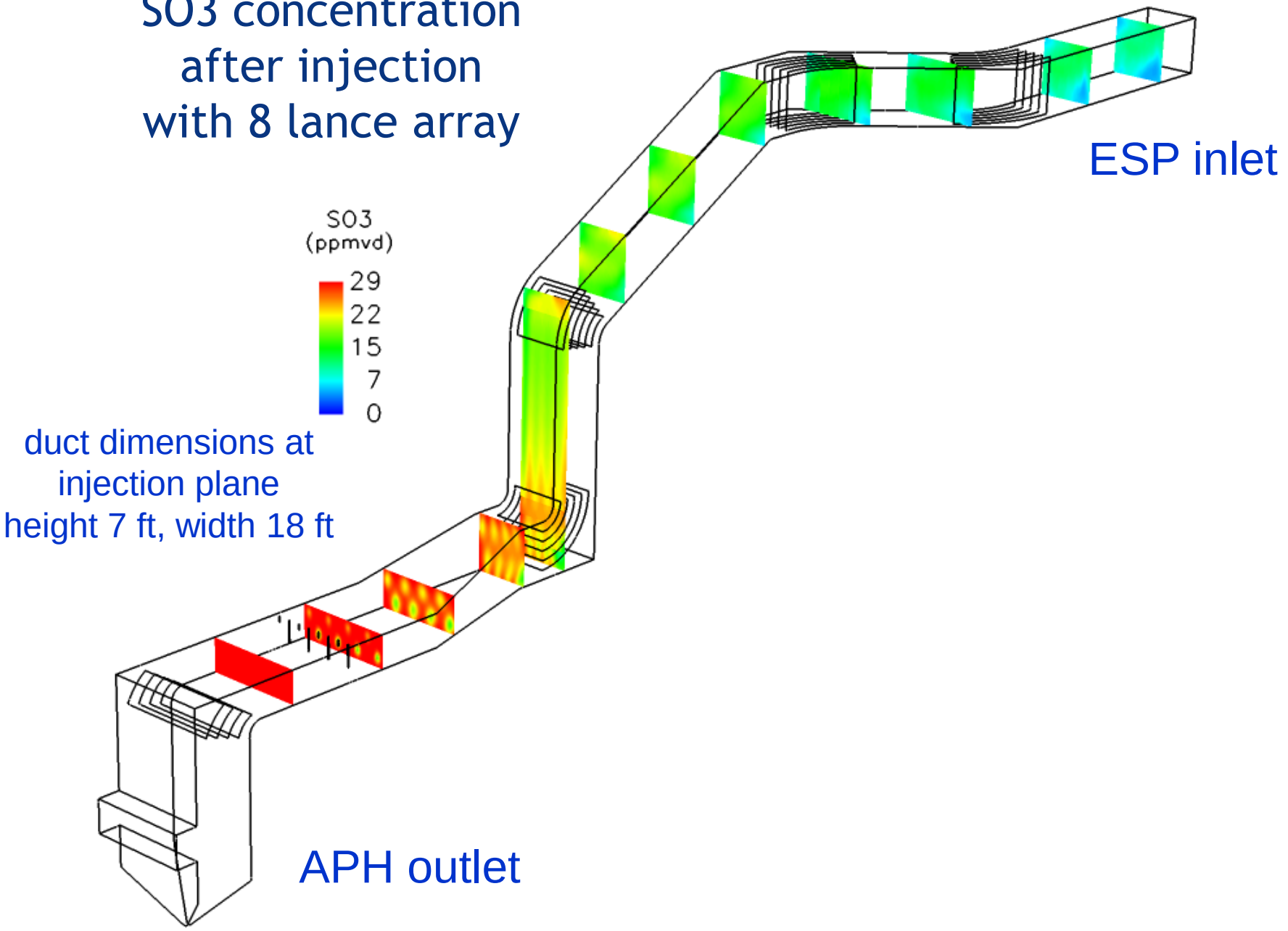
Sorbent concentration after injection with 8 lance array



duct dimensions at injection plane height 7 ft, width 18 ft

SO3 concentration after injection with 8 lance array



Nalco Mobotec SO_3 Capture Model

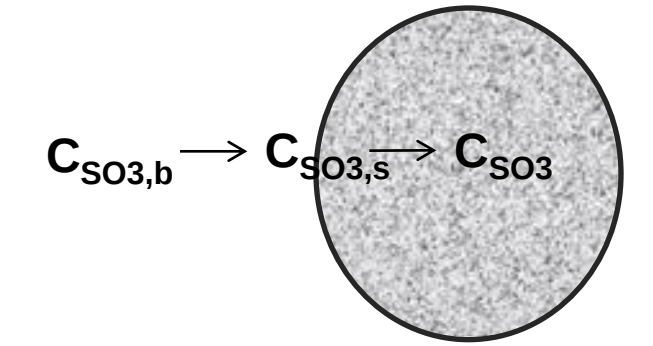
- Built on previous Mobotec model for furnace sorbent injection for SO_2 capture
- Solves SO_3 mass transfer and reaction equations simultaneous with sorbent particle dispersion equations
- Includes effects of:
  - Sorbent dispersion
  - Sorbent-gas contact time
  - Inlet SO_3 concentration
  - Gas temperature (post-APH range)
  - Sorbent injection rate
  - Sorbent properties

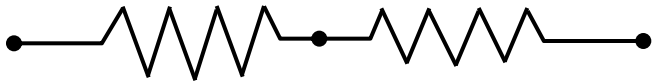
SO_3/Sorbent Sub-Model Description

- SO_3/H_2SO_4 transport by diffusion from bulk gas to gas film, to particle surface/pore opening, to reaction site in pore
- Far slower SO_3 diffusion inside pores
- Reaction rate at pore surface

  $SO_3 + Ca(OH)_2 \Rightarrow CaSO_4 + H_2O$

  $H_2SO_4 + Ca(OH)_2 = CaSO_4 + 2H_2O$

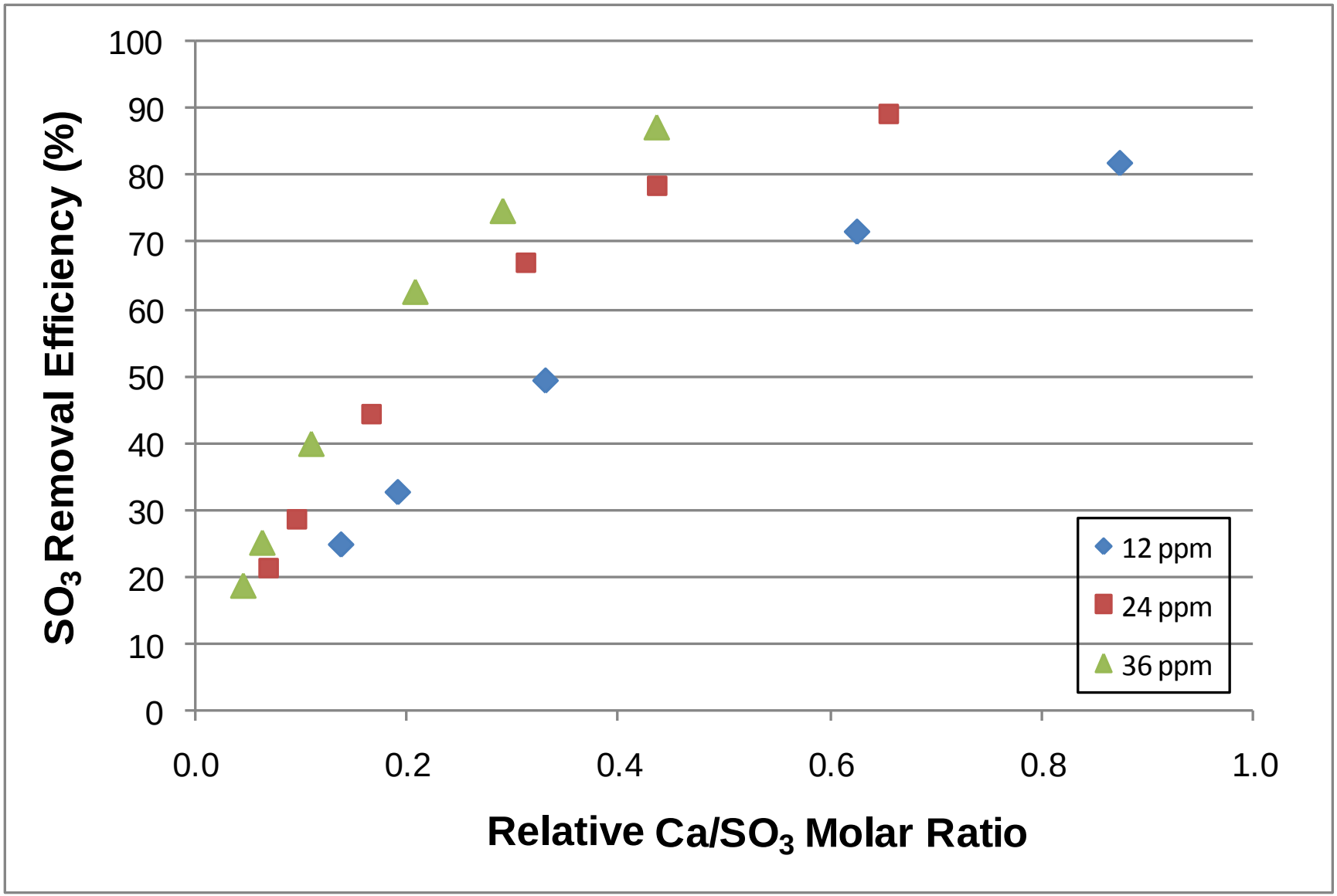




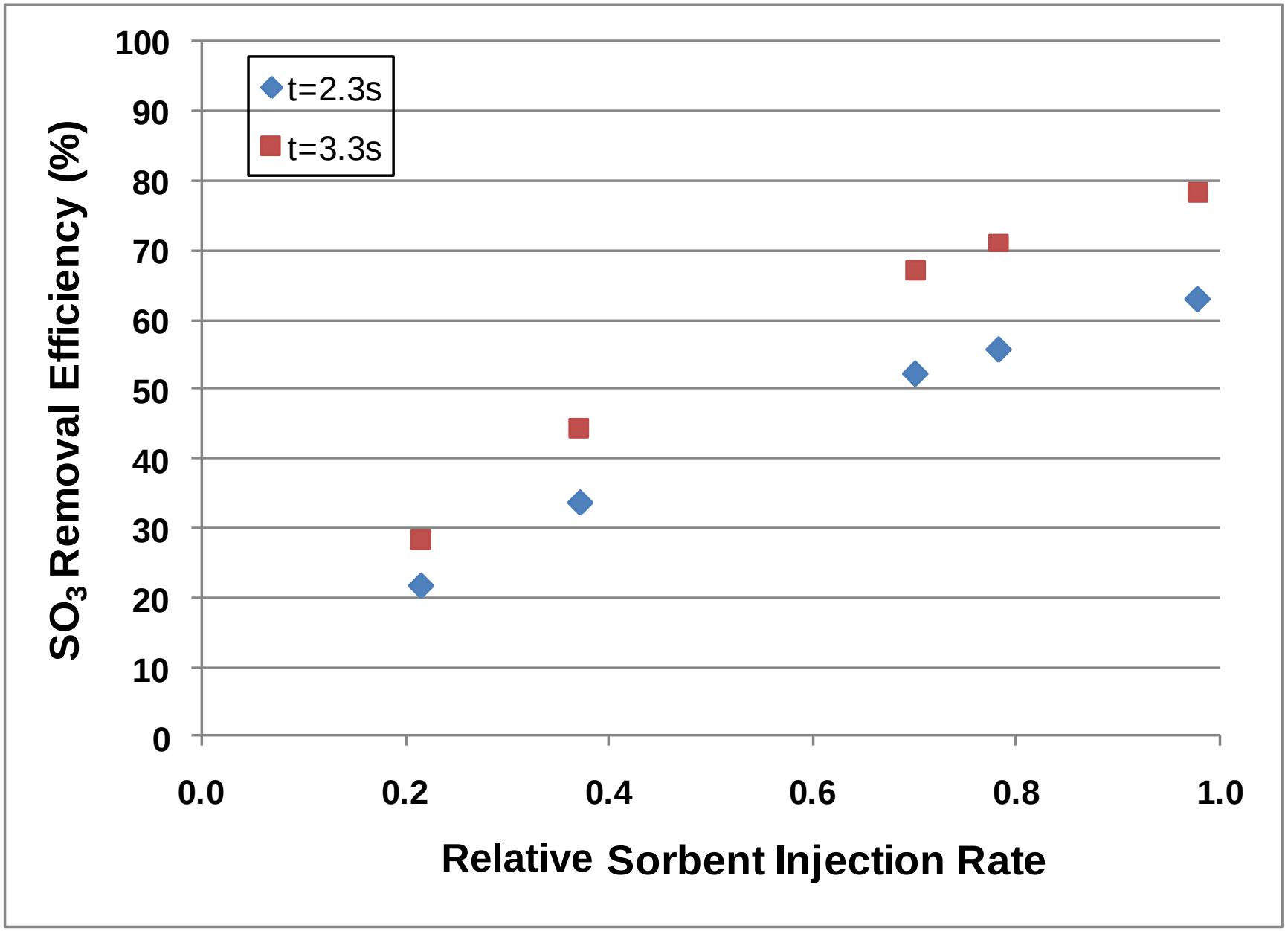
External resistance

Internal resistance

Effect of Inlet SO_3 Concentration



Effect of Sorbent-Gas Contact Time



Injection Trials

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- Uses portable injection equipment
- Provides performance data vs. injection rate for a particular unit
  - Can reduce required equipment size and cost
- Determine impact of sorbent on ESP or baghouse operation and on stack particulate emissions
- Examples of Nalco Mobotec trials
  - 300 MW PRB unit – SO2 and MACT HCl and Hg limits
  - 100 MW PRB unit – MACT HCl and Hg limits
  - Power boilers at paper mills – ICI MACT limits

DSI Trial Equipment

DSI Trial Equipment

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Summary of Presentation

- Why DSI for acid gas control?
- DSI applications of dry sorbent injection for SO2, SO3, HCl control at utility and industrial plants
- Nalco Mobotec capabilities for DSI
- Usefulness and necessity of CFD mass transfer and reaction modeling
  - SO_3 capture model predicts trends with injection rate, inlet SO_3 concentration, reaction time, sorbent properties
  - Other capture models under development