REINHOLD ENVIRONMENTAL Ltd.

2014 APC Round Table & Expo Presentation

July 14-15, 2014, in Louisville, KY / Hosted by LG&E/KU

All presentations posted on this website are copyrighted by Reinhold Environmental, Ltd (RE). Any unauthorized downloading, attempts to modify or to incorporate into other presentations, link to other websites, or obtain copies for any other uses than the training of attendees to RE's Conferences is expressively prohibited, unless approved in writing by RE or the original presenter. RE does not assume any liability for the accuracy or contents of any materials contained in this library which were presented and/or created by persons who were not employees of RE.

Flue Gas Mixing Technology Used in DSI Application

Matthew Quitadamo
Technical Advisor, Environmental Technology
July 15, 2014

© 2014 Information contained herein is proprietary and confidential to Babcock Power Inc.
All Rights Reserved

Babcock Power

Sorbent Injection Processes

Process Overview

- Sorbent is injected into a furnace and/or downstream section of ductwork for the capture of targeted contaminant emissions.

- Contaminants typically include:
  - Acid gases (SO_2, SO_3, HCl)
  - Other (Hg)

- Sorbents typically include:
  - Trona, SBC, hydrated lime, and activated carbon

- Choice of sorbent depends on type of pollutant, removal efficiency required, and system operating cost.

© 2014 Information contained herein is proprietary and confidential to Babcock Power Inc.
All Rights Reserved

Sorbent Injection Processes

Key Factors Affecting Performance

- Performance is influenced by:
  - Sorbent reactivity (chemical kinetics, particle properties, operating temperature)
  - Quantity of injected sorbent
  - Residence time (duct arrangement, accessibility)
  - **Sorbent coverage and dispersion**

"Proper mixing and dispersion of the injected sorbent into the temperature window required for maximum removal are more important than finding the optimum injection level of temperature."
- U.S. DOE, 2000

"Maintaining high capture efficiency with a relatively low carbon-to-mercury ratio requires relatively uniform dispersion of sorbent across the injection duct."
- Madsen et al., 2005

"Sorbent properties and sorbent dispersion once injected are critical to achieving high utilization of the sorbents."
- Senior et al., 2009

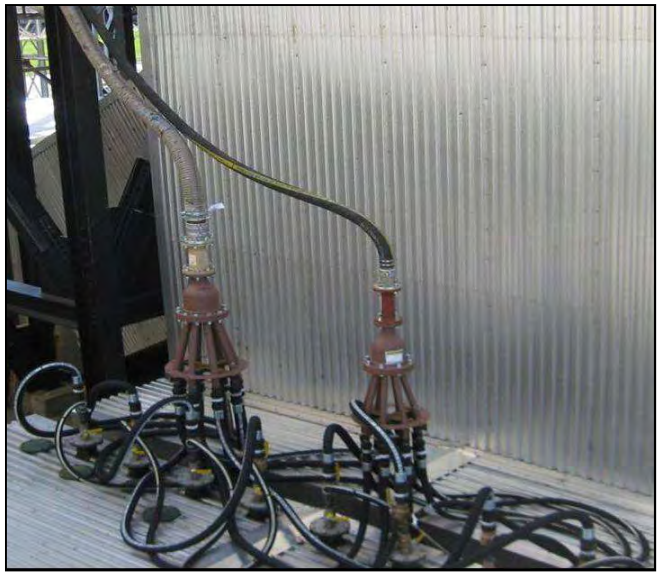
"Effective injection can reduce the total sorbent usage while minimizing the removal rates for unwanted chemical constituents."
- Hopkins et al., 2010

© 2014 Information contained herein is proprietary and confidential to Babcock Power Inc.
All Rights Reserved

Optimizing Coverage and Dispersion

Conventional Approaches

- Injection Grid
  - Large number of small diameter lances
    - Approximately 1 injection per every 40 to 45 square feet [Gentry, 2013]
    - Preferred aspect ratio for lance coverage area, H/W ~ 1 [Gentry, 2013]
    - Maintain acceptable SLR and transport velocity throughout conveying system
- Utilize presence of turbulence to enhance sorbent dispersion
  - Varies greatly from one system to the next

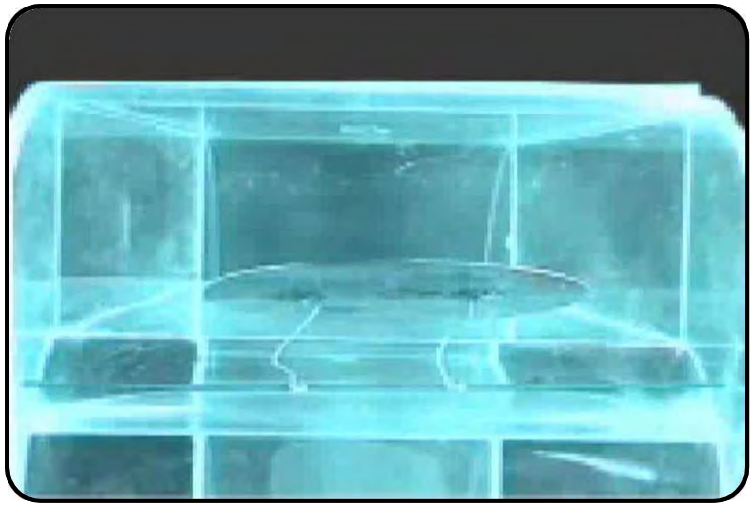


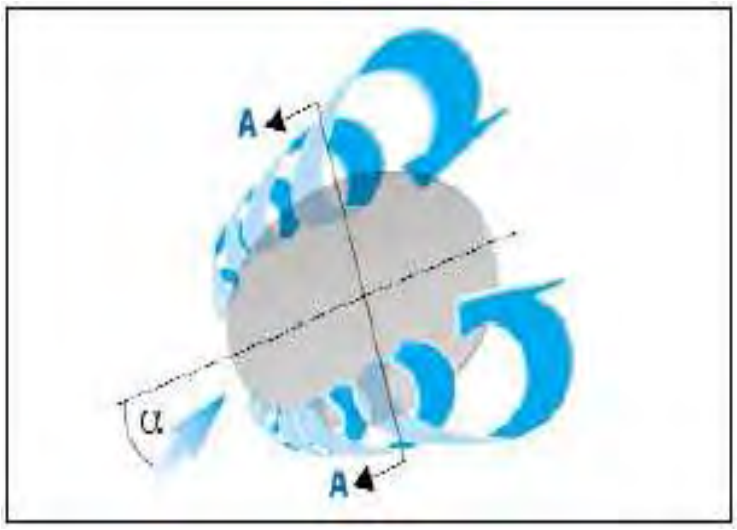
© 2014 Information contained herein is proprietary and confidential to Babcock Power Inc.
All Rights Reserved

Babcock Power

Optimizing Coverage and Dispersion

State-of-the-Art Approach





- Static mixers
  - Introduce streamwise vorticity to enhance in-duct mixing
    - Temperature
    - Velocity
    - Gas and solid concentrations
  - Several proven utility applications
    - SCR systems
    - Upstream ESP
    - Flue Gas Ducts
    - Chimney
    - Diffuser flow stabilization

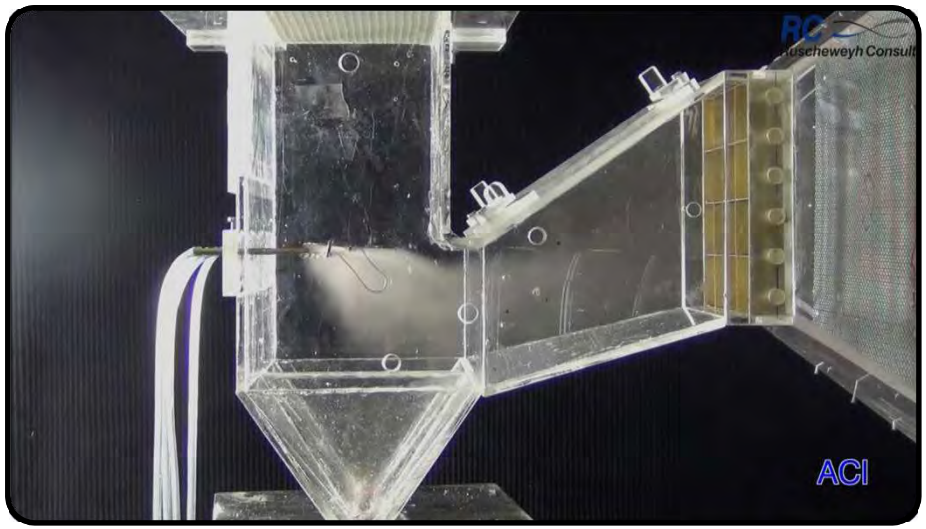
© 2014 Information contained herein is proprietary and confidential to Babcock Power Inc.
All Rights Reserved

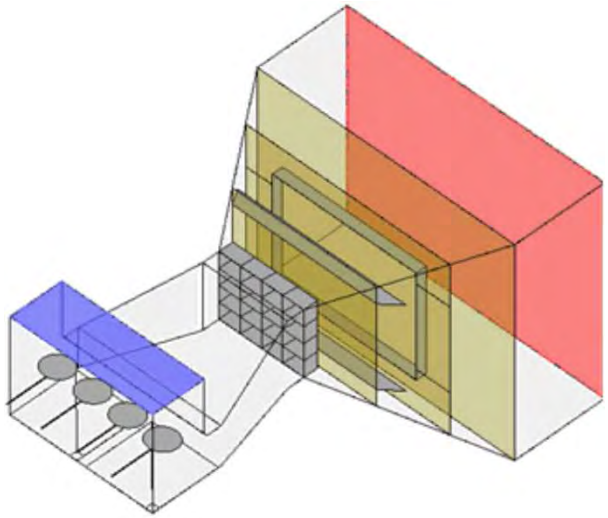
Babcock Power

Optimizing Coverage and Dispersion

Static Mixers for Sorbent Injection

- Reduced number of injection lances
- Larger lance diameter
- Near instantaneous mixing at point of injection
- Consistent sorbent coverage over entire load range
- Improved capture efficiency and/or sorbent consumption





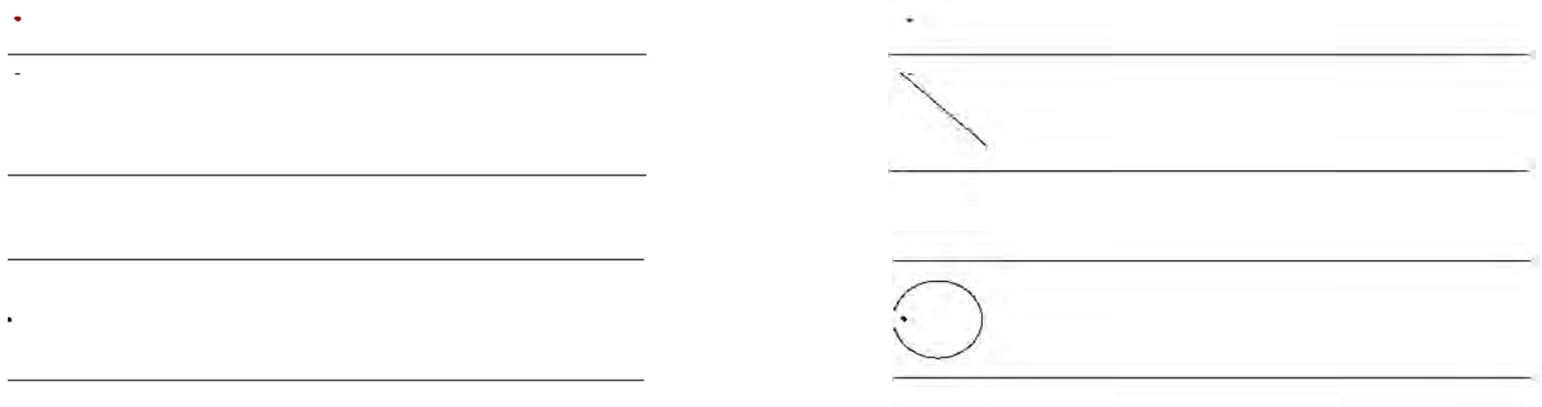
© 2014 Information contained herein is proprietary and confidential to Babcock Power Inc.
All Rights Reserved

Babcock Power

Conventional vs. Static Mixer Type Systems

Sorbent Dispersion and Coverage

Sorbent Injection **without** Static Mixers	Sorbent Injection **with** Static Mixers



Particle trajectories [colored by residence time]

for a single injection lance system with and without static mixing:

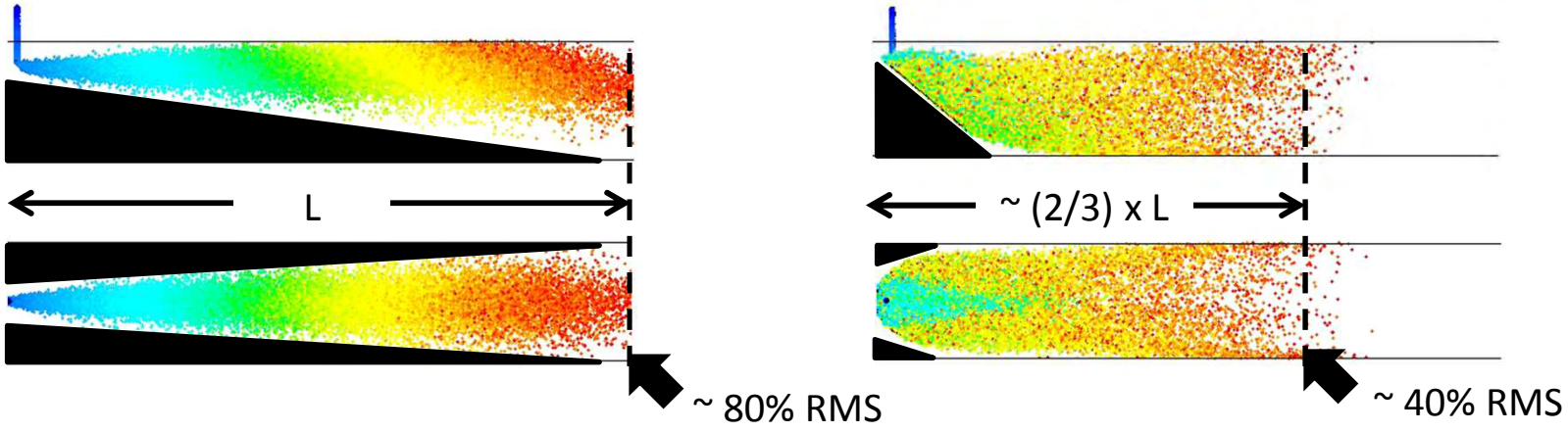
(*18' H x 18' W x 80' L duct segment, superficial gas velocity ~ 62 fps, D_{50}/D_{90} = 13/50 micron*)

© 2014 Information contained herein is proprietary and confidential to Babcock Power Inc.
All Rights Reserved

Conventional vs. Static Mixer Type Systems

Sorbent Dispersion and Coverage

Sorbent Injection **without** Static Mixers	Sorbent Injection **with** Static Mixers



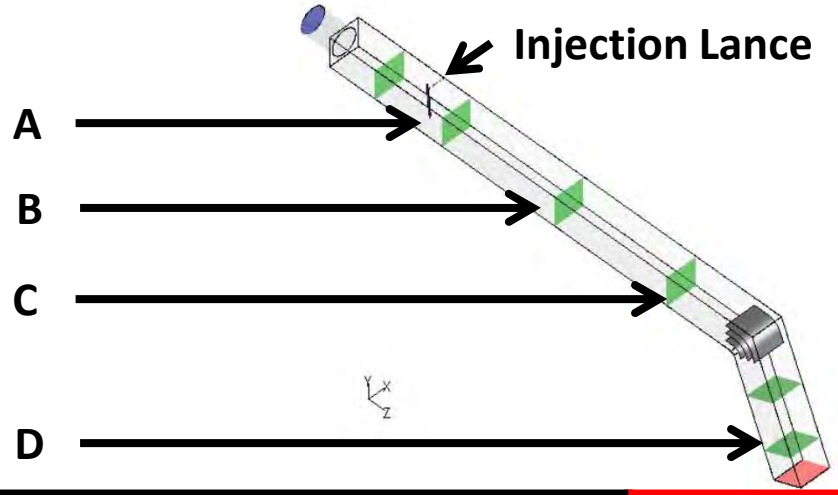
- Injection with static mixer provides:
  - Faster dispersion
  - Better coverage over a shorter length
  - Increased contact time
- To provide similar results, injection without mixers would require a 3 x 3 grid according to rules of thumb for conventional systems.

© 2014 Information contained herein is proprietary and confidential to Babcock Power Inc.
All Rights Reserved

Babcock Power

Conventional vs. Static Mixer Type Systems

Sorbent Coverage at Different Loads



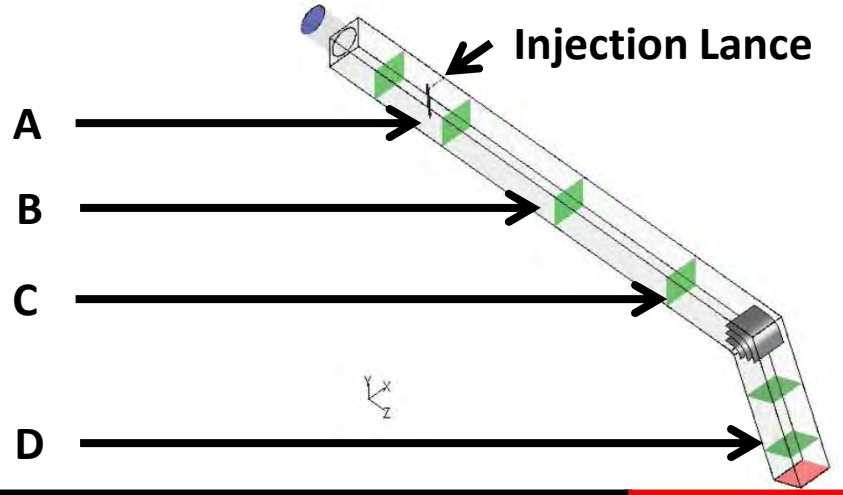
Contours of Particle Conc. [lb/ft^3]	Injection **without** static mixer				Injection **with** static mixer			
	A	B	C	D	A	B	C	D
100% Load								
50% Load								
25% Load								

© 2014 Information contained herein is proprietary and confidential to Babcock Power Inc.
All Rights Reserved

Babcock Power

Conventional vs. Static Mixer Type Systems

Sorbent Dispersion at Different Loads



Sorbent Distribution [% RMS]	Injection **without** static mixer				Injection **with** static mixer			
	A	**B**	**C**	**D**	**A**	**B**	**C**	**D**
100% Load	297	111	80	57	90	42	39	17
50% Load	267	91	49	33	78	27	29	14
25% Load	223	82	56	40	69	23	23	12

© 2014 Information contained herein is proprietary and confidential to Babcock Power Inc.
All Rights Reserved

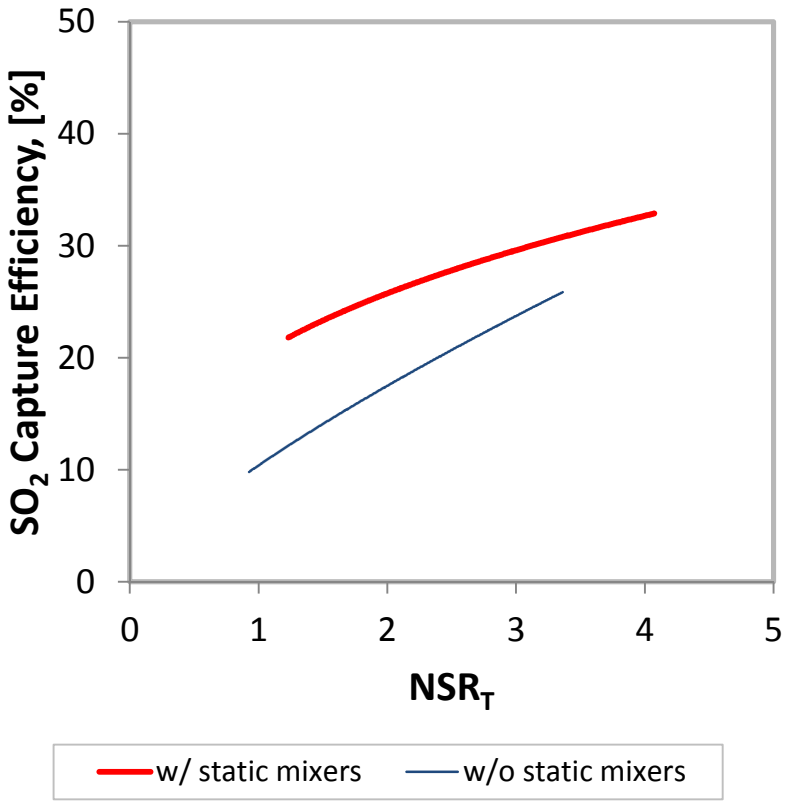
Babcock Power

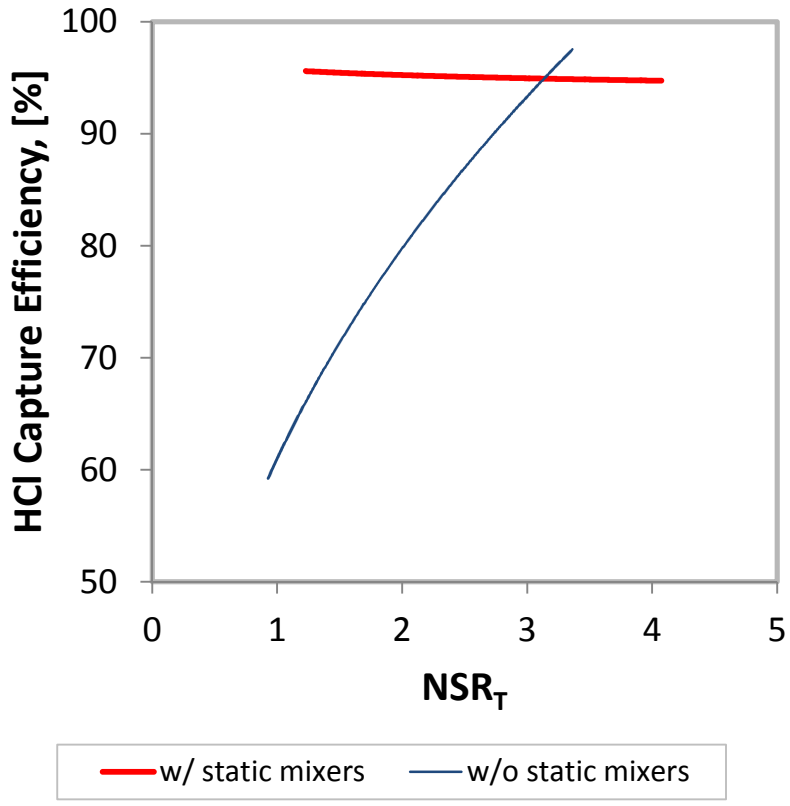
Conventional vs. Static Mixer Type Systems

Capture Efficiency and Sorbent Consumption

2012 & 2013 Test data from TVA Shawnee Unit 2.

Sorbent: Hydrated Lime, Injection Location: Downstream Econ./Upstream AH, PCD: Fabric Filter





© 2014 Information contained herein is proprietary and confidential to Babcock Power Inc.
All Rights Reserved

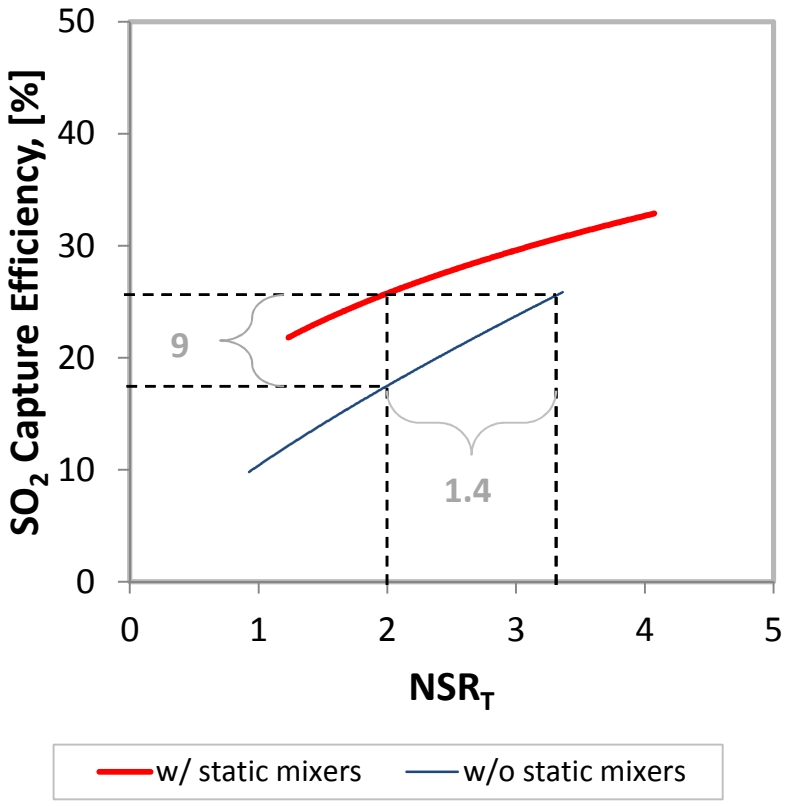
Babcock Power

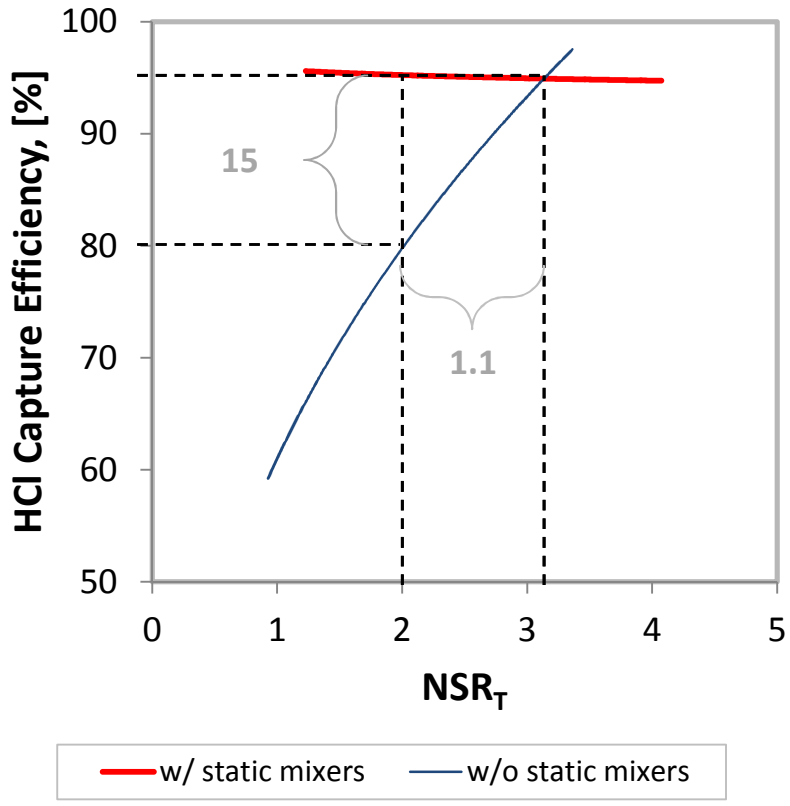
Conventional vs. Static Mixer Type Systems

Capture Efficiency and Sorbent Consumption

2012 & 2013 Test data from TVA Shawnee Unit 2.

Sorbent: Hydrated Lime, Injection Location: Downstream Econ./Upstream AH, PCD: Fabric Filter





© 2014 Information contained herein is proprietary and confidential to Babcock Power Inc.
All Rights Reserved

Babcock Power

Conventional vs. Static Mixer Type Systems

Summary

- Dispersion is critical to sorbent injection applications
- Static mixers have been successfully applied to several utility applications, including in-duct sorbent injection
- Use of static mixers can result in:
  - Reduced number of injection lances required
  - Improved sorbent coverage throughout the system
  - Consistent coverage across the full range of operating conditions
- Test results from full scale utility system demonstrates improved emissions reduction and/or reduced sorbent consumption

© 2014 Information contained herein is proprietary and confidential to Babcock Power Inc.
All Rights Reserved

Babcock Power

Flue Gas Mixing Technology Used in DSI Application

References

- Gentry, Matt. (2013, July 8-9). *CFD and Physical Modeling of DSI/ACI Distribution*. Poster session presented at the Reinhold APC Round Table & Exposition, St. Louis, MO.

- Hopkins, M.W. and Muoh, O. F. (2010, June 6-10). Predicting PAC, Hydrated Lime, and Trona Effectiveness in Flue Gas Systems using CFD and Physical Analyses for Optimized Nozzle Design. Paper presented at the 35th International Technical Conference on Coal Utilization & Fuel Systems, Clearwater, Florida.

- Madsen, Jens I., Starns, Travis, Rogers, William A., and O'Brien, Thomas J. (2005, October 19-21). The impact of Turbulent Mixing on Sorbent Dispersion in Coal-Derived Flue Gases. Paper presented at International Conference on Air Quality V., Arlington, VA.

- Senior, Constance, Wang, Huafeng, Wilson, Jeff, and Irvin, Nick. (2009, June 16-19). Computational Fluid Dynamic Modeling of SO3 Capture by Sorbents in Coal Flue Gas. Paper presented at 102nd Air and Waste Management Association Annual Conference and Exhibition, Detroit, MI.

- U.S. Department of Energy. (2000). LIMB Demonstration Project Extension and Coolside Demonstration: A DOE Assessment (DOE Report No. DOE/NETL-2000/1123). Retrieved from http://www.netl.doe.gov/technologies/coalpower/cctc/resources/pdfs/limb/netl1123.pdf

© 2014 Information contained herein is proprietary and confidential to Babcock Power Inc.
All Rights Reserved