Reinhold Environmental Ltd.

2008 APC Round Table & Expo Presentation

July 13-15, 2008, in Savannah, GA

Panel IV – Scrubber Upgrades



2008 APC Round Table and Expo

July 13, 2008

Savannah, GA

Panel Members

- Gordon Maller, URS – Reliability and Operability
- Greg Bielawski, B&W – Gas-Side Mass Transfer Improvements
- Jim Sutton, Alstom – Spray Headers and Spray Nozzles
- Mark Golightley, First Energy – Bruce Mansfield Unit 3 Upgrade
- Melissa Allen, TVA – Widows Creek 7 Upgrade
- Joe Tomlinson, Pacificorp – Hunter Unit 1 and 2 Upgrade
- Jerry Presley, Dominion – DBA Use at Mt Storm 3

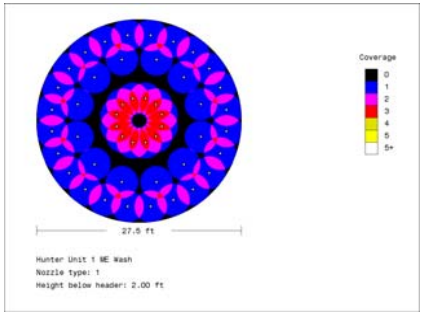
Reliability and Operability Considerations

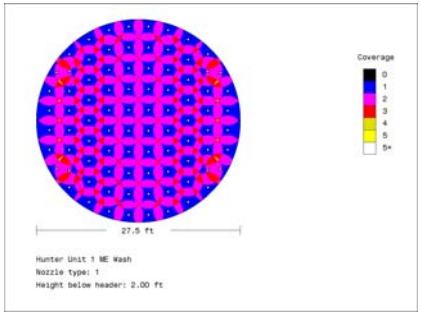
- Reliability: Availability and capability of the scrubber, and scrubbing systems and equipment to achieve and sustain design performance levels
- Operability: Ability of the control systems to operate and control the scrubber to achieve and sustain design performance levels

Both must be considered and successfully dealt with for an upgrade to be successful

Reliability Issues

- ME Performance:
  - Increased velocity
  - Tendency for fouling and scaling
  - Poorly designed wash system
- Oxidation Air System:
  - Tendency for sulfite blinding may increase with increased removal
- Reagent Preparation:
  - Capacity may need to increase





Reliability Issues (continued)

- Materials:
  - Corrosion
    - Tightening of water balance
    - CS linings may be damaged during demo and construction
  - Erosion
    - Internal erosion of piping
    - External wear due to spray spray impingement
- Scaling:
  - Chemical
  - Wet-dry interfaces

Operability Issues

- Control Loops:
  - Slurry density (solids concentration)
  - Reaction tank level
  - Reagent addition
- Control Systems:
  - PLC or DCS rather than single-loop controllers

Conclusion

- Reliability and operability issues usually do not arise as a result of performance improvement work.
- Nevertheless, they need to be dealt with for the utility to see the value of the improvement work.
- Otherwise, scrubber will continue to run as poorly as it always has.

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Options to Improve Gas-Side Mass Transfer:

Tray vs Rings

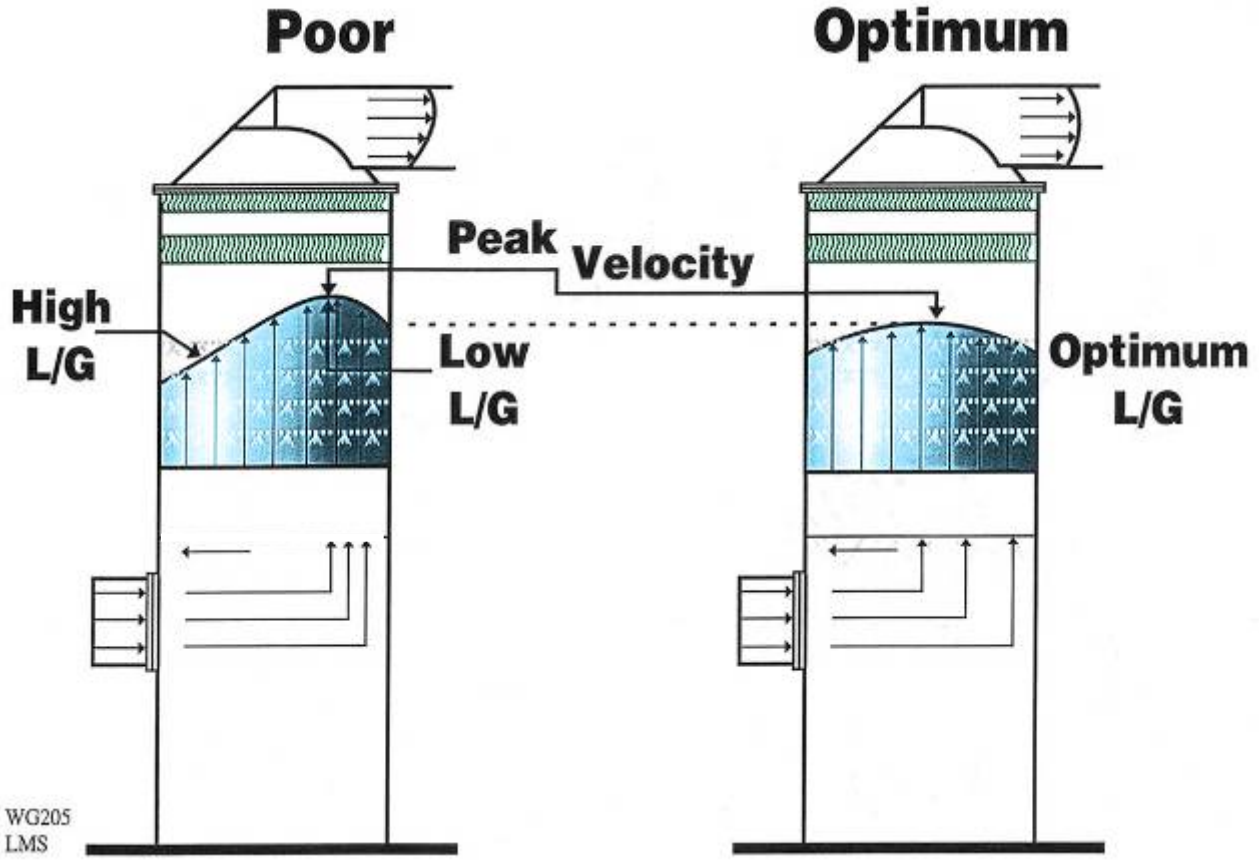
Greg Bielawski
Environmental Aftermarket Services

In a Wet FGD Absorber: A Very Heavy Rainstorm !

Imagine the heaviest rainstorm you have experienced, which might be 6 inches of rain per hour.

100 L/G (gal/1000 ft^3 of flue gas) in a Wet FGD absorber operating at a typical 12 foot per second superficial gas velocity is equivalent to a rainfall of ~7000 inches per hour !

Importance of Gas Flow Distribution



- Improved SO_2 removal
- Less carryover to ME

What is Wall Sneakage?

Wall region

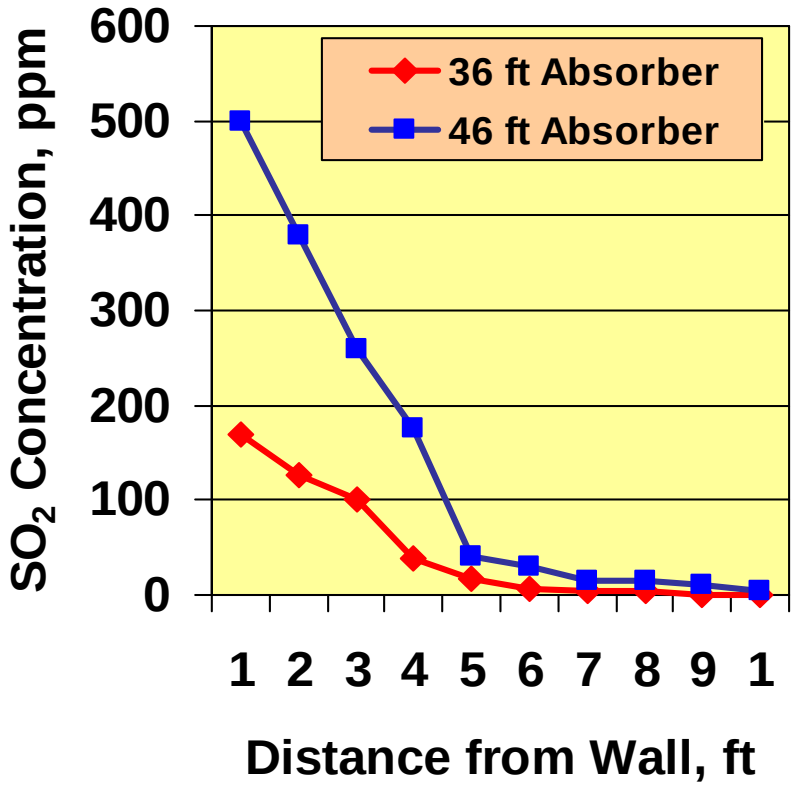
- reduced liquid density
- increased gas velocity
- much reduced SO_2 removal

Tower center

- better than required gas/liquid contact
- SO_2 removed to extinction

Overall

- untapped potential
- sets maximum SO_2 removal to less 94-96%

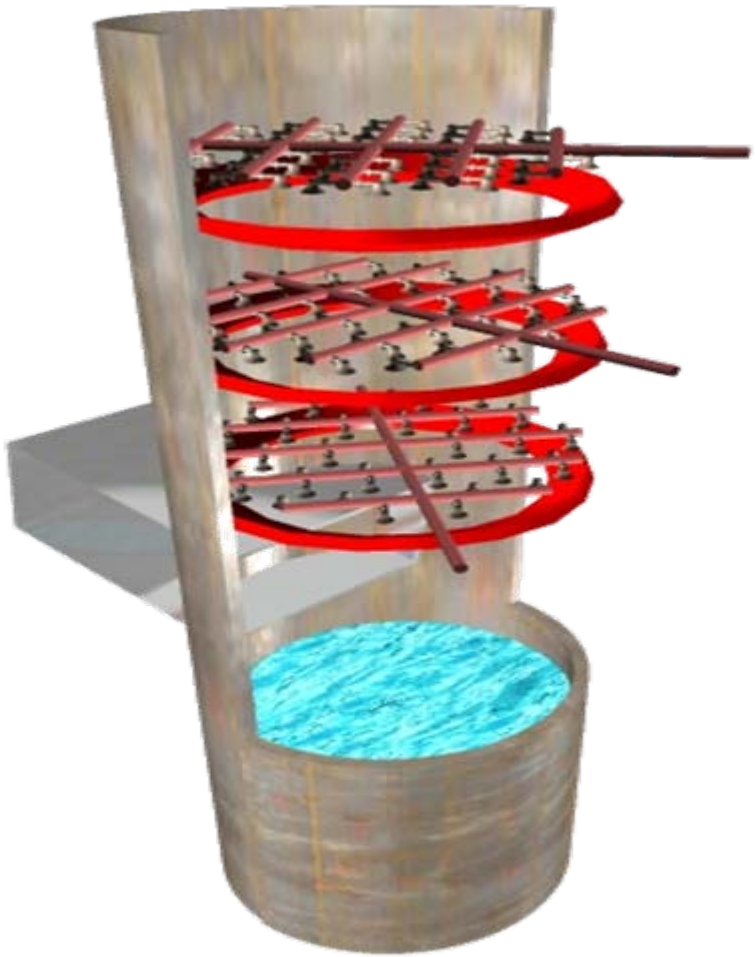


Source: URS

What are Liquid Distribution Rings?
(also called Wall Rings)

Located below each spray level

- **Redistributes gas away from absorber wall**
- **Redistributes liquid running down absorber walls**
- **Improves SO_2 removal performance**
- **Nominal impact on pressure drop**

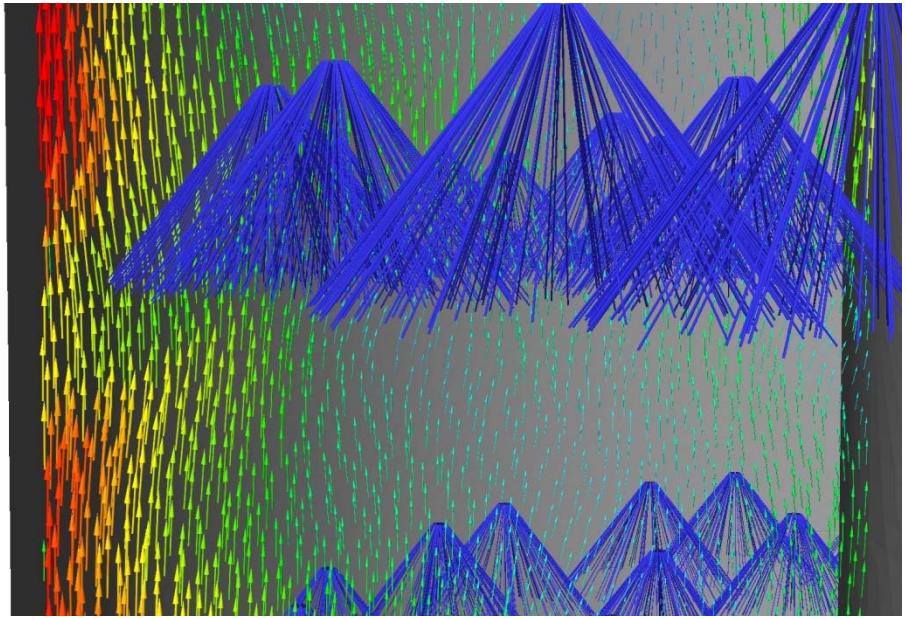


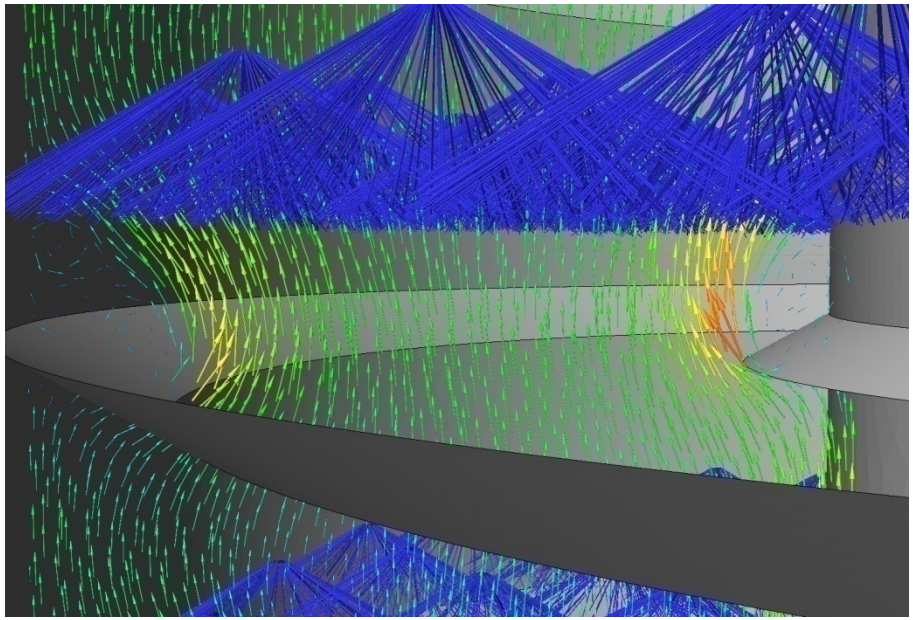
Source: URS

Liquid Distribution (Wall) Rings

Purpose:

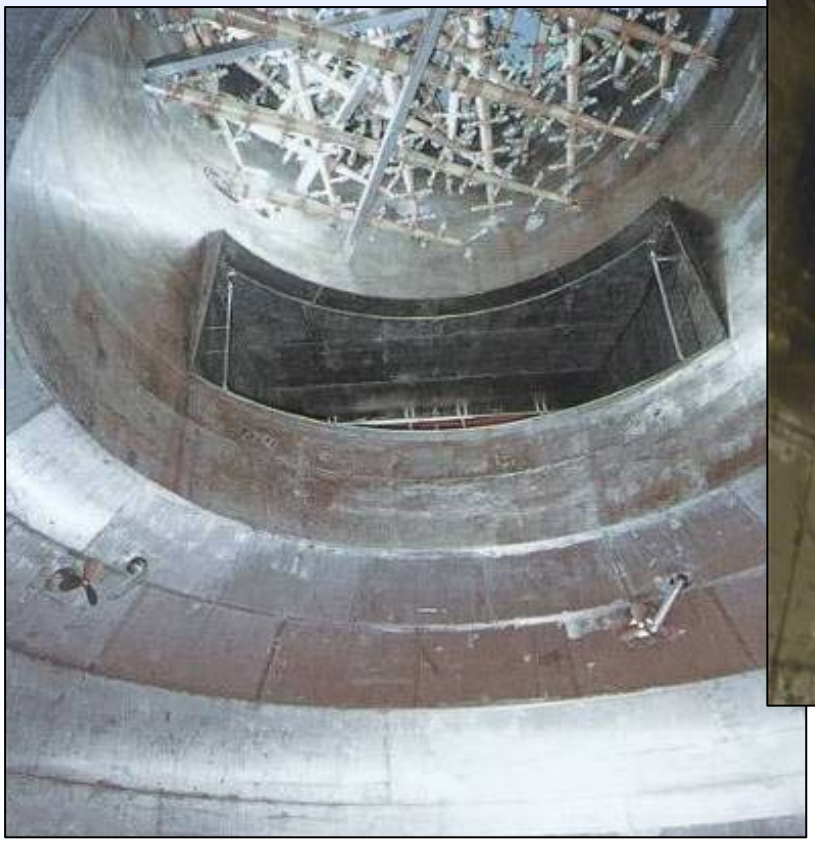
- **Reduce or eliminate wall sneakage**
- **Enhance gas-liquid contact**

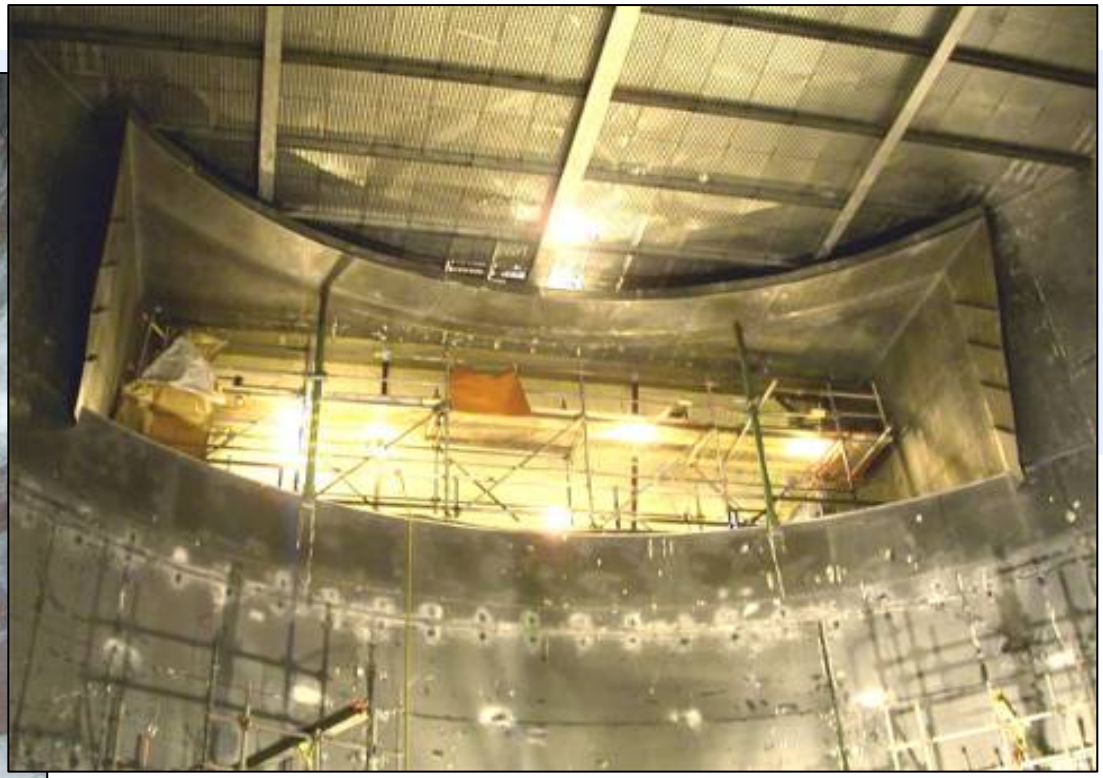




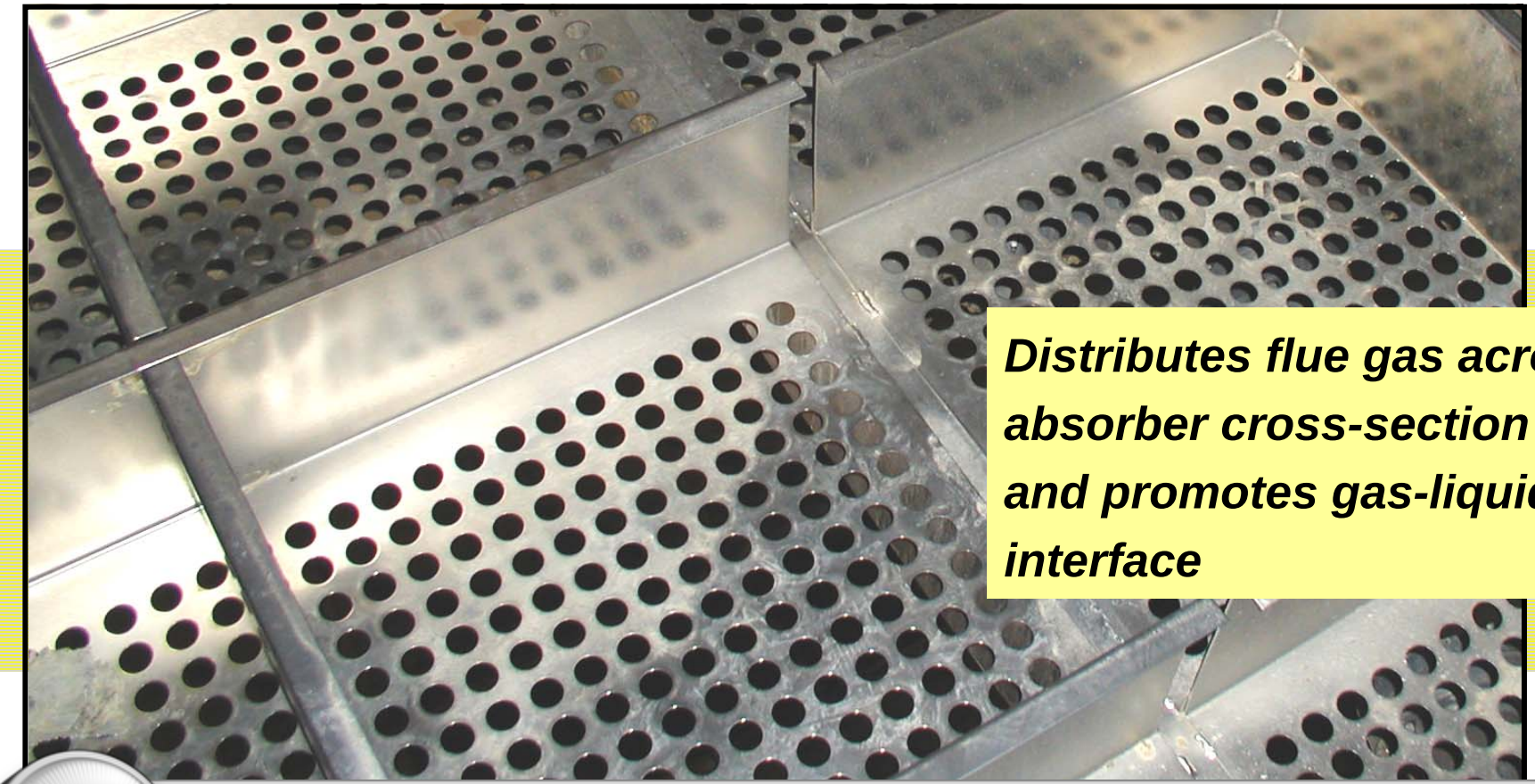
Source: URS

Open Spray Tower with or without Wall Rings *vs* *Spray Tower With Tray*





Tray Stays Clean in Service



Distributes flue gas across absorber cross-section and promotes gas-liquid interface

Two-Year Outage Inspection (No Cleaning)

Tray Reduces Power Consumption

Fixed Conditions:

Unit Size	**500 MW**
SO_2 Inlet	**1,800 ppmdv**
SO_2 Removal	**95%**
Reagent	**Limestone**

	With Tray	***Without Tray***
Stoichiometry	1.03	1.03
L/G (Total)	80 gal/macf	110 gal/macf
Pressure drop	5.0 in. wg	3.5 In. wg
Pump power	2,760 KW	3,750 KW
Fan power *	6,860 KW	6,580 KW
Total power	9,620 KW	10,330 KW

* Based on single speed ID fan with 25-inch water static rise

Power savings: 710 KW

Tray vs Wall Rings

Tray distributes gas before the spray zone… most effective use of the entire spray zone height.

Tray a more effective contactor… less L/G required for the same SO_2 removal. One less absorber pump than spray tower with wall rings.

Tower with tray has higher pressure drop than spray tower with wall rings ... However, one less absorber pump means lower total auxiliary power consumption.

Advent of forced oxidation prevents scaling in all Wet FGD systems.

Wall Rings are a quiescent zone in spray tower, leading to localized buildups… The presence buildups must be recognized when entering tower during an outage.

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Options to Improve Gas-Side Mass Transfer:

Tray vs Rings

Thank You.

WFGD Upgrade
Spray Header & Nozzle Design
July 14, 2008

2008 APC/PCUG Conference

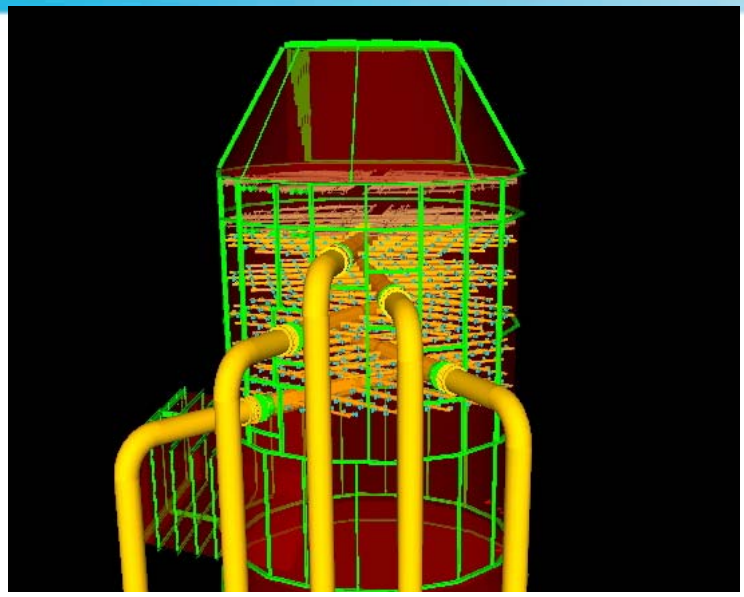
POWER

Presented by : Jim Sutton

ALSTOM

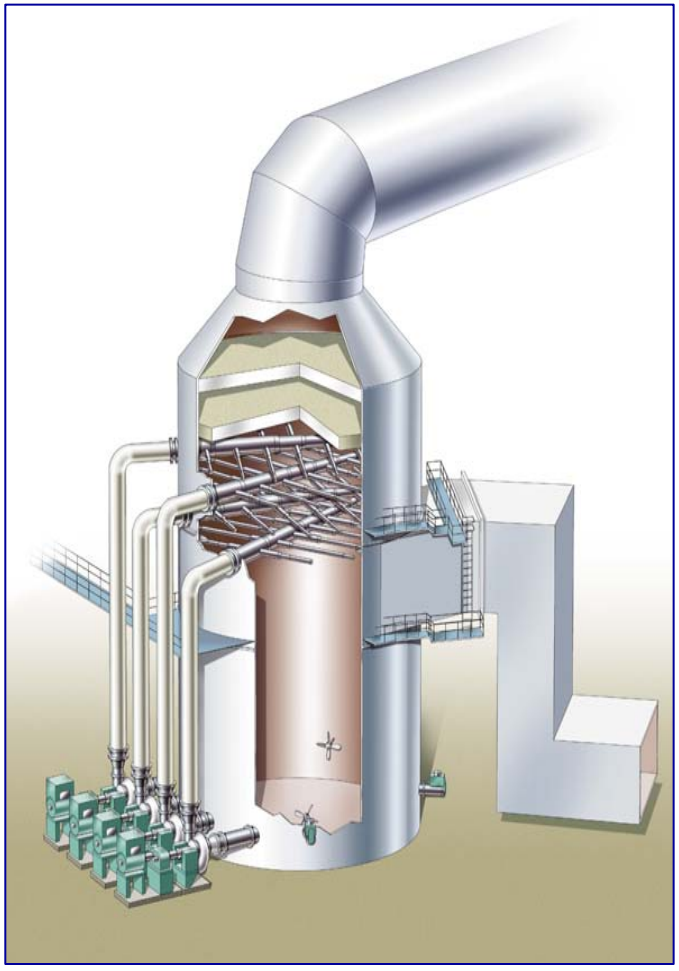
Spray Zone

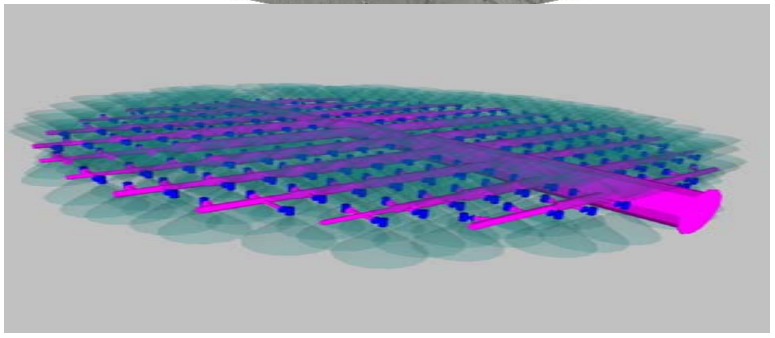
- Multiple spray levels with dedicated pumps allows efficient turndown
  - optimized for various loads, fuels to reduce operating costs: 100 0% Load
- Absorber gas velocity:
  - Typical design: 10-14 ft/sec
  - Lower design velocity results in reduced pressure drop, higher capital costs



- Spray flow
  - Typical afternoon thunderstorm: 1-2 in/hr
  - Spray tower: 3 ft/min
  - Per nozzle 250 – 500 gpm

Absorption Zone Modifications



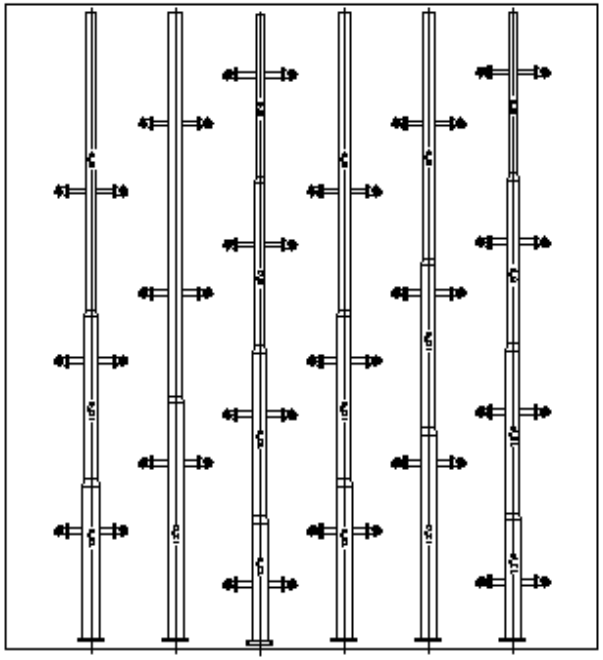


- Improve gas / liquid contact for high removal efficiencies
- Improved coverage/spray overlap
- PEP Plate/ Flow Distribution Tray
- Minimal draft loss increase

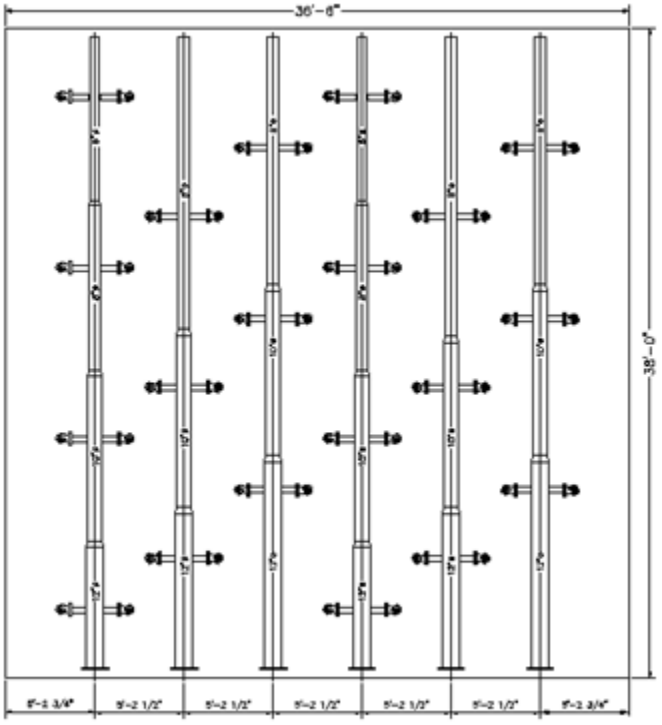
Recycle Slurry Spray Nozzles

- Slurry atomization for efficient gas/liquid interaction and mass transfer
- Sauter mean droplet diameter of ~2,400 micron at 8 psig
- Typical nozzle specification
  - Nitride-bonded silicon carbide
  - Hollow-cone spray
  - Single and dual orifice
  - 120° spray angle
  - 8 psig (0.55 – 0.7 bar g)
  - 250-500 gpm
- Dual Orifice Nozzles
  - Similar to conventional hollow cone nozzles except spray up and down
  - Use in lower levels to improve efficiency
  - Silicon carbide; 250-500 gpm

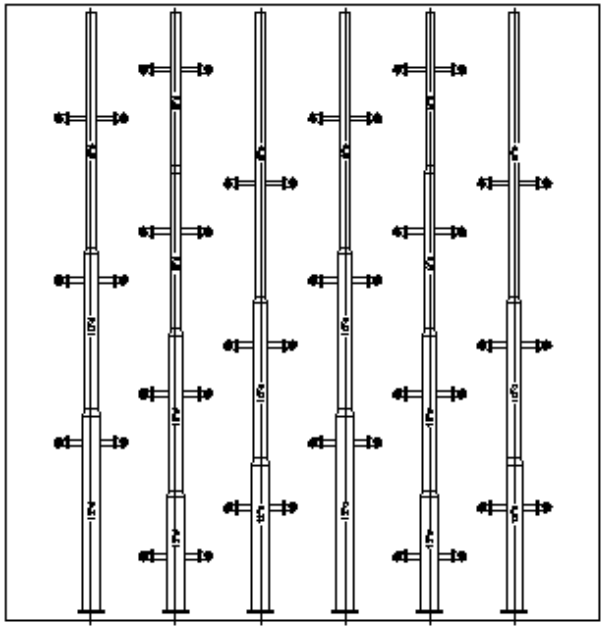
Staggered Spray Header Layouts



RECYCLE SPRAY HEADER LAYOUT
LEVEL 3



RECYCLE SPRAY HEADER LAYOUT
LEVELS 1 & 4

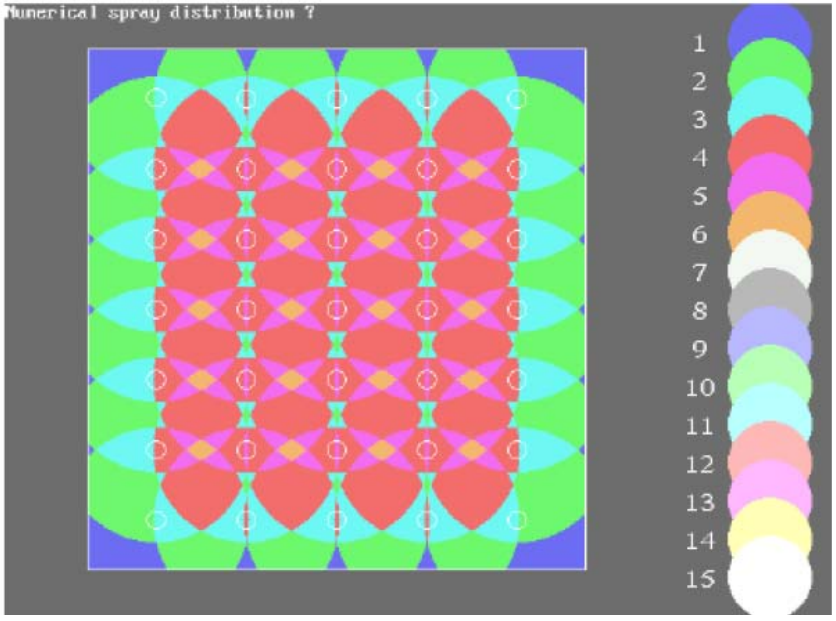


RECYCLE SPRAY HEADER LAYOUT
LEVEL 2

POWER ALSTOM

Spray Distribution- Utility Installation in USA

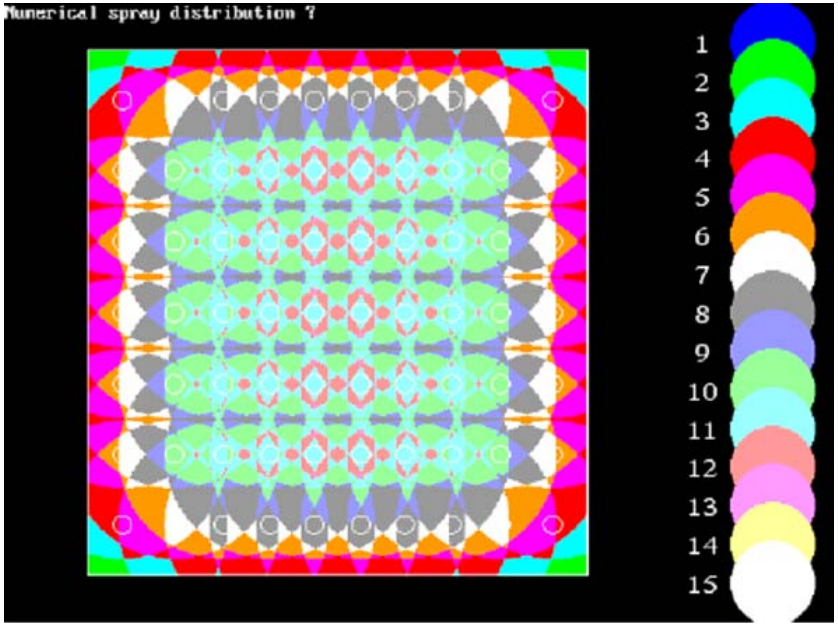
Before Changing Spray Headers



Spray Distribution Statistical Data

Spray Zone Coverage - Overall	99.5%
Spray Zone Coverage – 1 Spray	5%
Spray Zone Coverage – 2 Sprays	25%
Spray Zone Coverage – 3 Sprays	16%
Spray Zone Coverage – 4 Sprays	40%
Spray Zone Coverage ≥ 5 Sprays	14%
Spray on Walls	8%
Nozzles per Spray Level	35

After Changing Spray Headers



Spray Distribution Statistical Data

Spray Zone Coverage - Overall	100%
Spray Zone Coverage – 7 Spray	8%
Spray Zone Coverage – 8 Sprays	17%
Spray Zone Coverage – 9 Sprays	7%
Spray Zone Coverage – 10 Sprays	19%
Spray Zone Coverage – 11 Sprays	15%
Spray Zone Coverage – 12 Sprays	6%
Spray on Walls	13%
Nozzles per Spray Level	70

POWER ALSTOM

FGD Upgrades @ FirstEnergy's Bruce Mansfield Unit 3

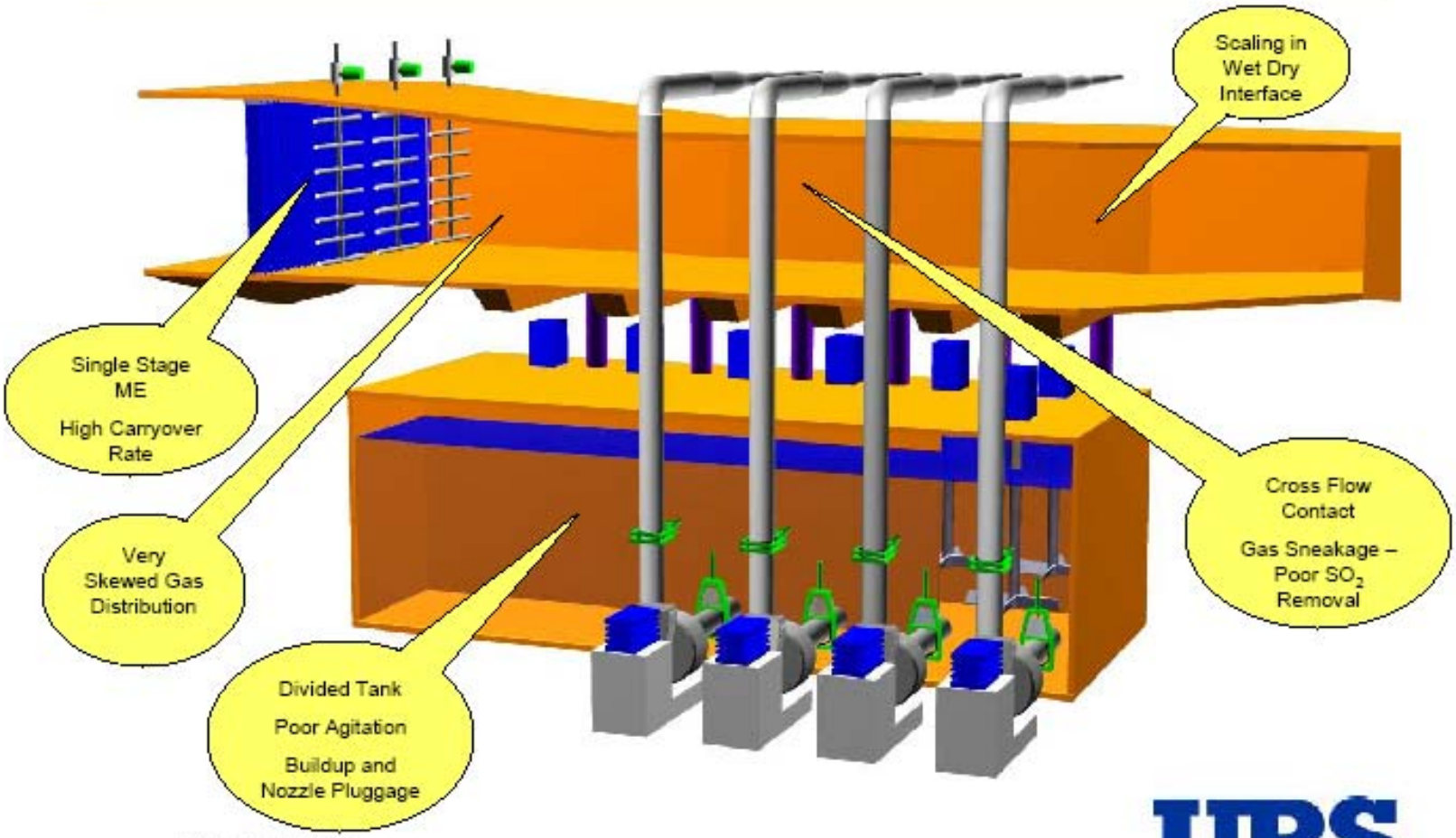
PCUG Mtg. – July 14, 2008

Scrubber Upgrades Panel

Project Goals

- Upgrade SO2 Rem Eff from ~92% to >95%
- Replace outdated recycle pumps
- Upgrade inlet zone metallurgy
- Possibly reduce stack rain with increasing gas flow

Current Design



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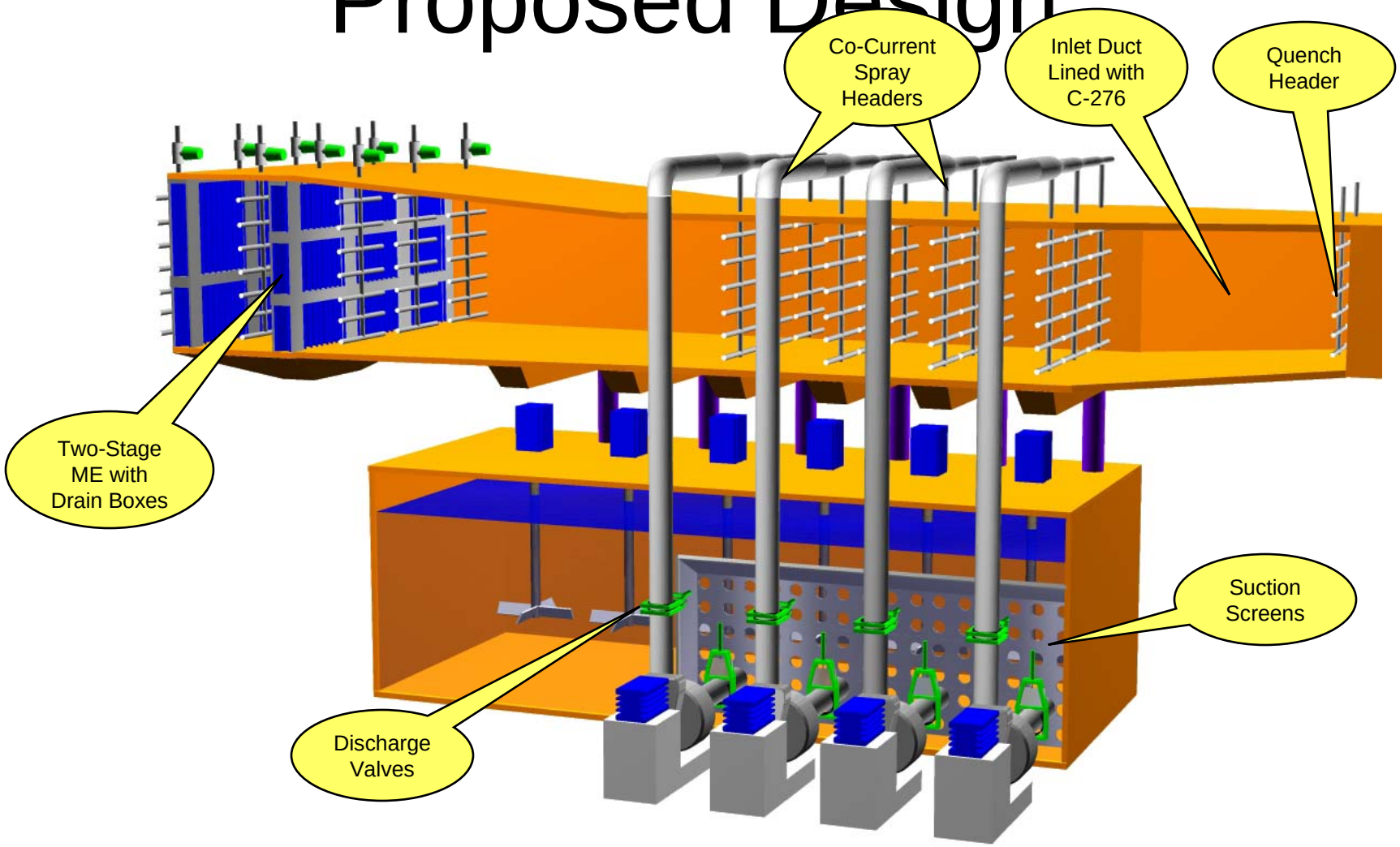
Proposed Design



Scrubber Upgrades Panel

TVA Widows Creek Unit 7 SO_2 Removal Efficiency Improvement Project

Melissa Allen

System Engineer

Tennessee Valley Authority

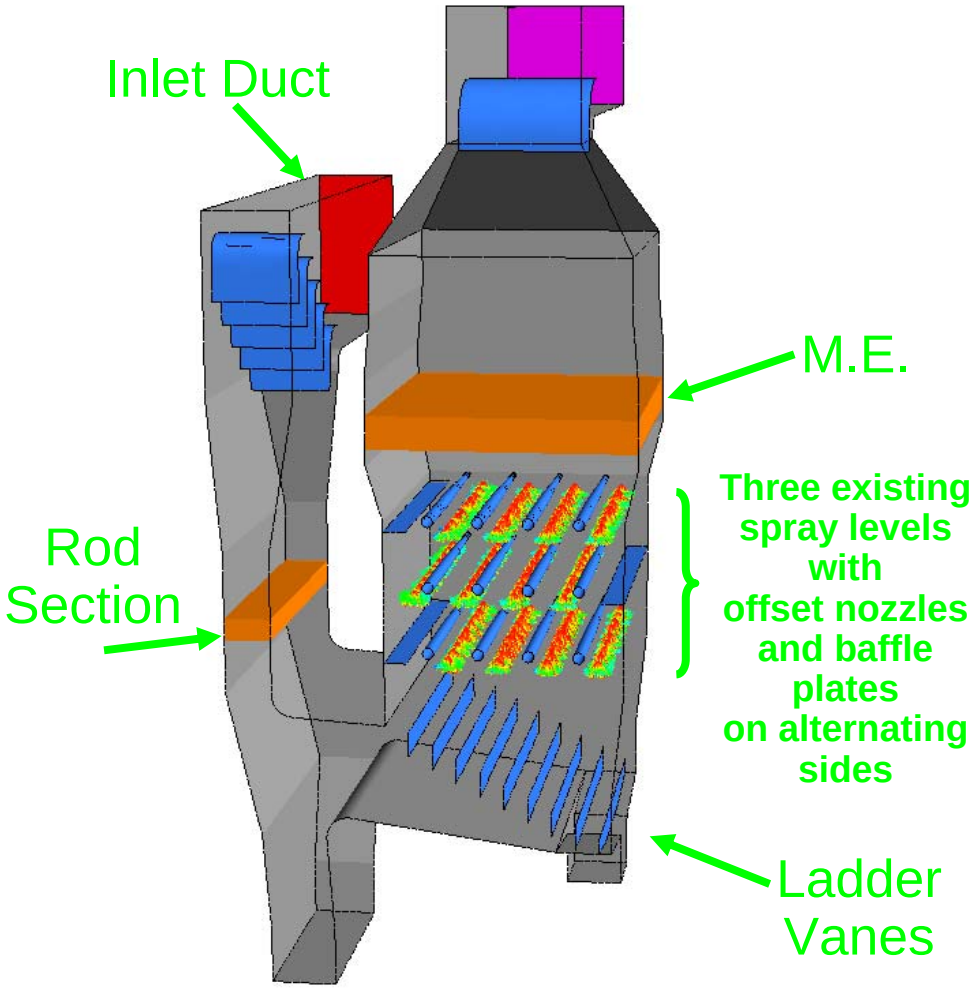
July 14, 2008

Scrubber Upgrades Panel

Widows Creek Unit 7 Scrubber

- Stevenson, Alabama
- 500 MW High Sulfur Coal (4.5 lb/MMBtu SO_2)
- 1981 Alstom design (formerly Combustion Engineering)
- Wet limestone forced oxidation
- 4 parallel modules with rod & absorber sections

Scrubber Upgrades Panel



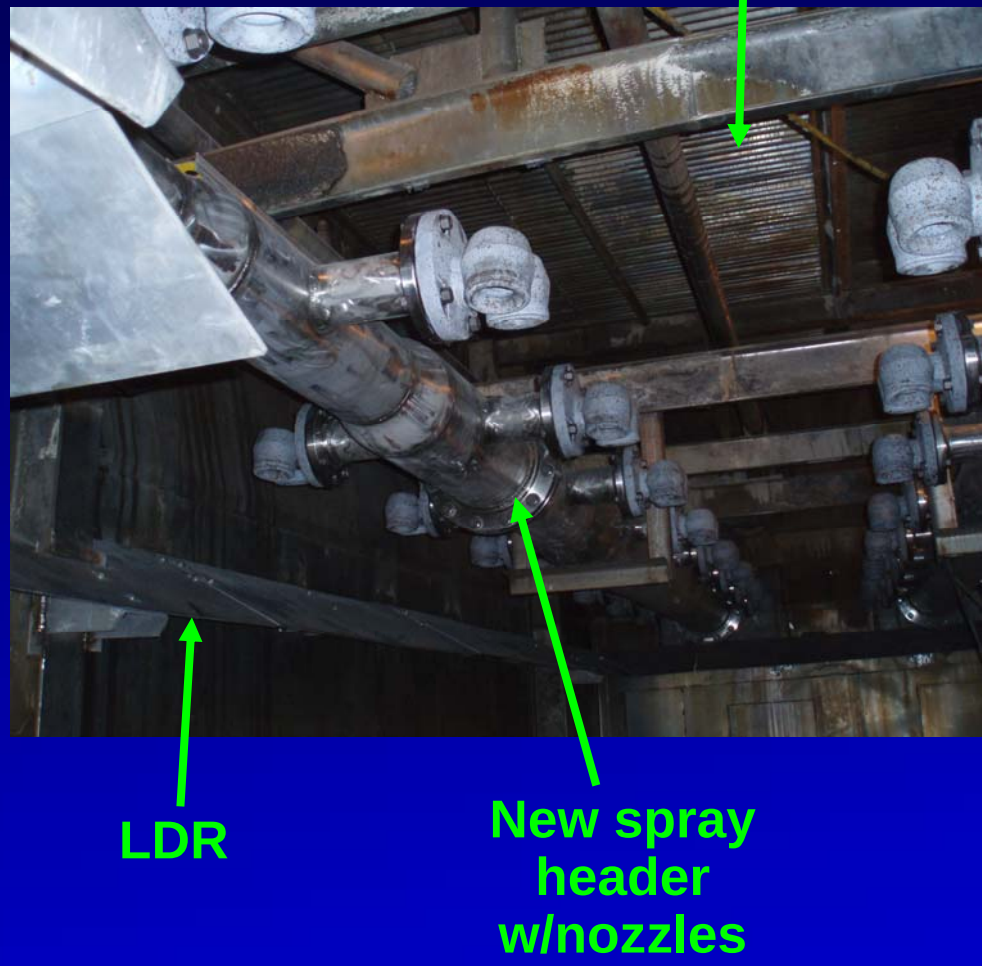
Configuration Before Upgrade

- 94% removal with 3 absorber pumps in service
- 91% removal with 2 absorber pumps in service
- Slurry pH 5.7-5.8
- Absorber tower contained 3 baffle plates installed by TVA previously
- 90^{o} spray nozzle
- 36 spray nozzles / level

Scrubber Upgrades Panel

Configuration After Upgrade

- 72 spray nozzles / level
- 120^{o} spray nozzle (Lechler Twinabsorb)
- TVA baffle plates removed
- Liquid distribution rings (LDR) installed under each spray level



Scrubber Upgrades Panel

Performance After Upgrade

- 98% SO_2 removal with 3 absorber pumps in service
- 95% SO_2 removal with 2 absorber pumps in service
- Slurry pH 5.7-5.8
- Pressure drop increase minimal
- No problems with slurry oxidation

Hunter Station

- Generation

  Unit 1- 430 Net MW

  Unit 2- 430 Net MW

  Unit 3- 460 Net MW

- Fuel

  - HV Bituminous

  - Sulfur Content, 0.3-0.8%

  - Ash Content, 9.0-14.0%

- Pollution Control Devices

  Units 1 and 2

  - Buell ESP

  - Chemico Open Spray Wet Lime, 80% SO_2 Removal (10% Bypass)

  Unit 3

  - Full Reverse Air Baghouse

  - GEESI Open Spray Wet Lime, 90% SO_2 Removal and 0.1 lb/MMBtu

Historical FGD Problems

- **Internal Recycle Piping**
  - Internal and External Pipe Erosion
  - Spray Nozzle Pluggage
  - Tower Wall Spray Impingement
  - Piping Support Erosion and Corrosion
- **Mist Elimination System**
  - Mist Eliminator Pluggage
  - Mist Elimination Wash Failure
  - Slurry Carryover Into Outlet Duct and Stack
- **Absorber Tower Shell**
  - Internal Coating Failures
  - Inlet Duct Solids Deposition

Solutions

- Computational Fluid Dynamics (CFD) Flow Modeling of Existing System
- CFD Flow Modeling to Evaluate Optimization Options
- Identify Retrofits Necessary to Achieve SO_2 Removal Optimization
- Economic Evaluation of the Retrofits

Completed Retrofits

- Install Liquid Distribution Rings to Improve Gas Distribution
- Improve Spray Header Design and Nozzle Layout to Optimize Gas/Liquid Contact
- Install Inlet Gas Flow Straightening Vanes to Eliminate Solids Deposition in Inlet Duct
- Optimize Mist Elimination System to Reduce Slurry Carryover Into Outlet Duct and Stack

Observed Performance of the Installed Retrofit

- SO2 removal rates are now easily achieved with 4 tower operation and 50% of the installed recycle capacity
- SO2 removal rates are now easily achieved with 3 tower operation and 50% of the installed recycle capacity
- No recycle piping problems or observed nozzle pluggage for the past 3 to 4 years of operation
- Visual inspection of mist eliminators reveal no pluggage or scale deposition
- Eliminate Cleaning Costs of Ductwork and Stack
- Lowered Absorber Pressure Drop by 2" H2O

Mt Storm Unit 3 Scrubber Operating with Dba

Presented by Jerry Presley, P.E.
Consulting Engineer
Dominion Resources Services, Inc.

Mt Storm Unit 3 Scrubber

550 MWg Pulverized Coal Fired Unit

Located in NE, WV

Scrubber Retrofit – Commercial January 1995

Dominion's first operating scrubber

Wet Limestone Force Oxidation, with 2 x 50% absorber vessels

Dominion

Mt Storm Unit 3 Scrubber

Supplied by GEESI

Dba system was part of the original scope

Acid was used in 1995 & 1996, but not 1997-2000. Acid was originally added directly to the absorber vessels.

Beginning in 2001, acid use was re-evaluated and has been used since. Acid is now added to the limestone slurry tanks.

Acid use now considered essential to meet the requirements of our Consent Decree

Mt Storm Scrubber Dba Operation

- Typically operate between 400 and 800 ppm acid level.
- Acid is added approximately every 5 days
- Adipic Acid has been used when acid tank needed repairs
- Adipic Acid less effective than Dba due to time needed to dissolve
- Dba very cost effective, with increased removal efficiency at less than $100/ton

Contacts

For more information contact:

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Dominion