

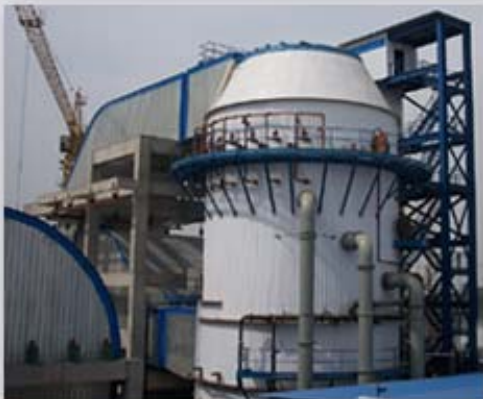
REINHOLD ENVIRONMENTAL Ltd.



2010 APC Round Table & Expo Presentation

July 18-20, 2010, in Concord, NC / Hosted by Duke Energy

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MARSULEX

ENVIRONMENTAL TECHNOLOGIES

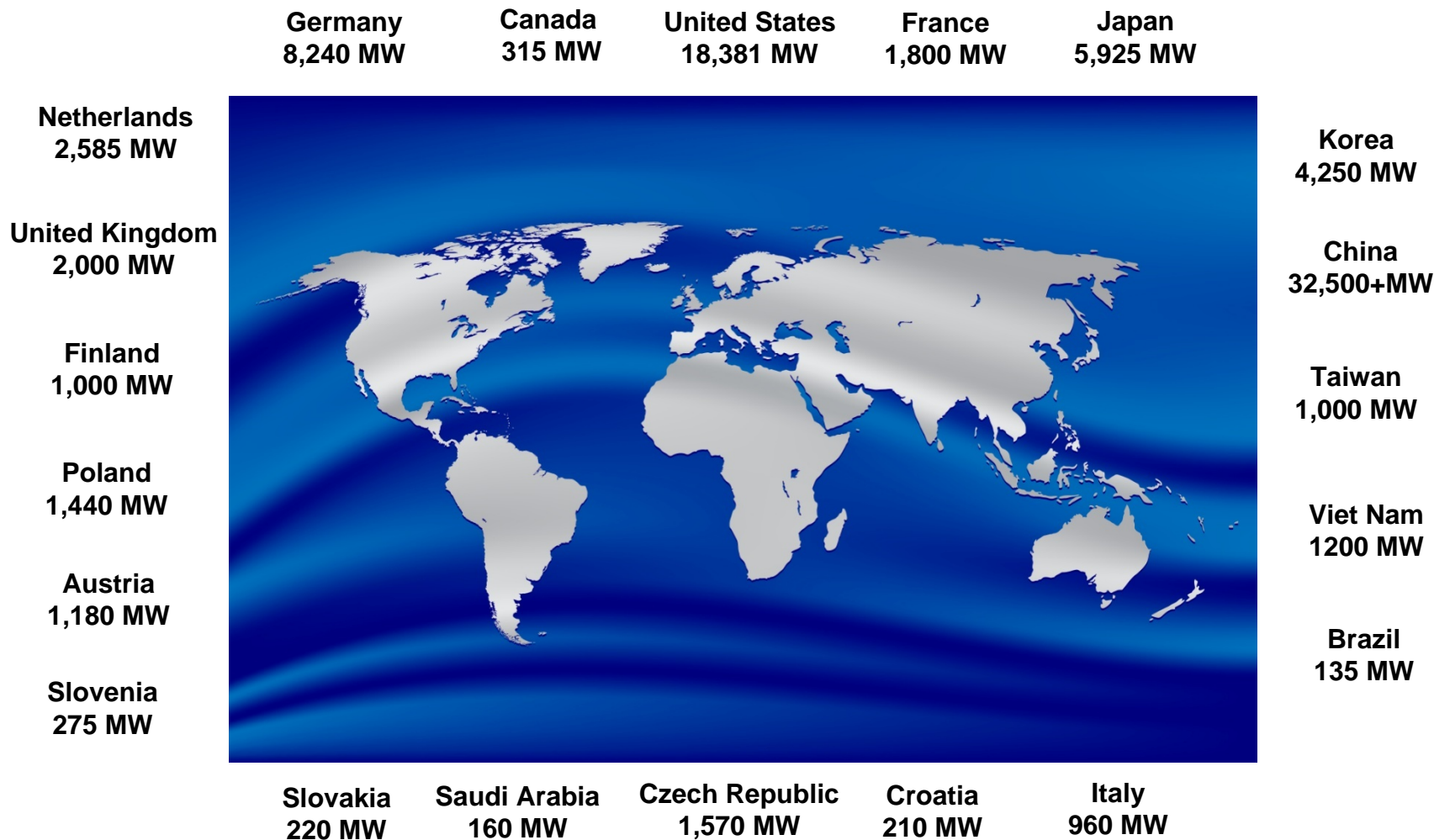


Improving Existing Scrubber Performance

Mike Hammer, Senior Process Engineer

SOLUTIONS. PERFORMANCE. RELATIONSHIPS.

MET FGD Installations



Points of Discussion

- Historical Practice
- Upgrade Drivers
- Gas Flow Considerations
- Liquid Side Considerations
- Reagent Change
- Case Studies



Historical Practice

Wet FGDs of the 1970's – 1980's did not reflect today's design approaches:

- Lower SO₂ removal performance
- Spare towers
- Bypass
- Packing
- Double-Loop and other unique process designs

Upgrade Drivers

Today's Requirements / Preferences Drive Updates:

- Boost SO₂ removal / reduce other emissions
- Fully scrub (eliminate bypass)
- Reduce maintenance and operation costs
- Fuel switching
- By-product and / or reagent changes



Gas Flow Considerations

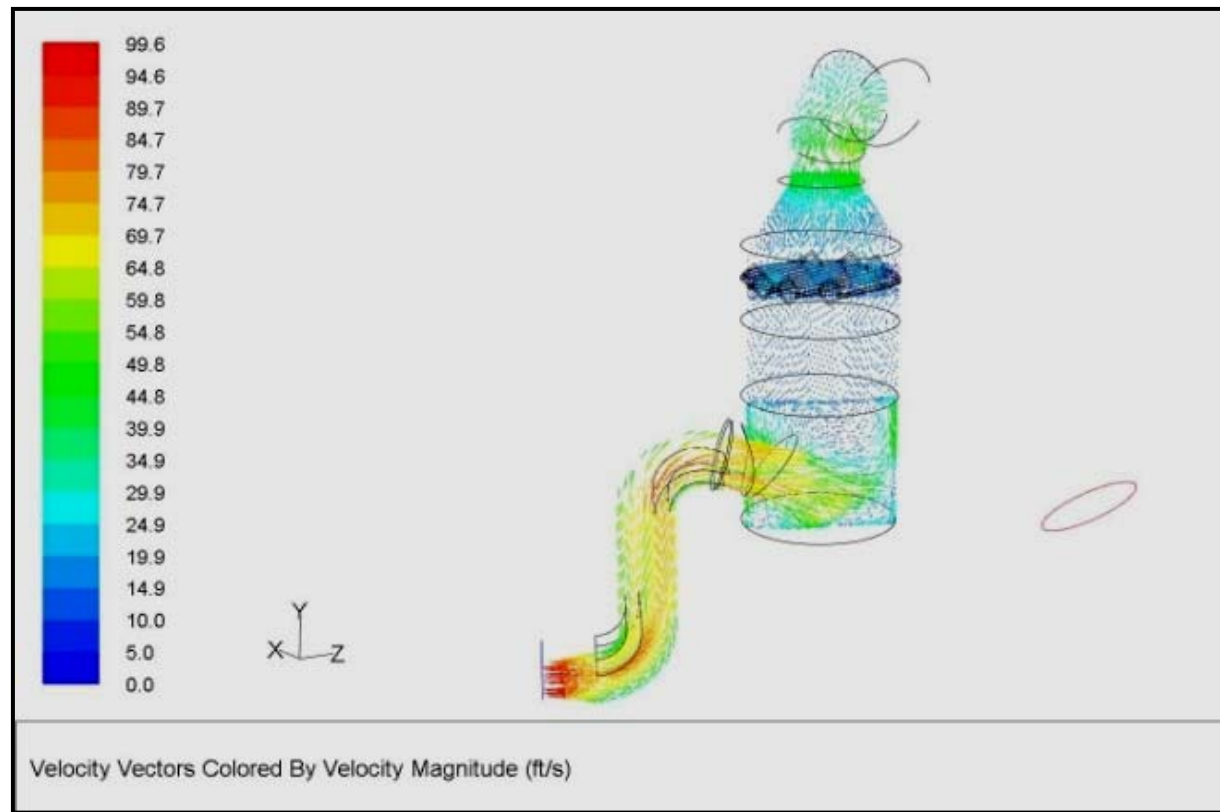
- Ductwork
- Bypass
- Reheat
- Booster Fan
- Mist Eliminator Performance

Assessment via Computation Fluid Dynamics

Gas Flow Considerations

Perform Computation Fluid Dynamic (CFD) Model

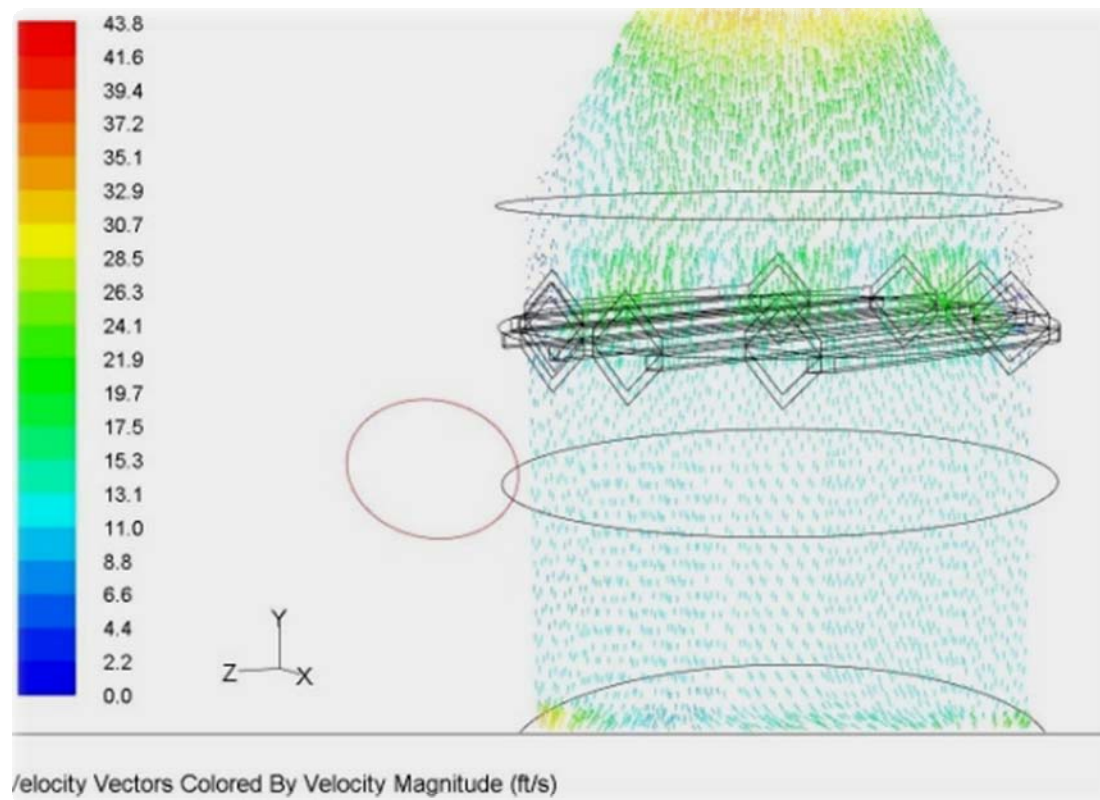
- A. Assess Current System Condition
- B. Assess Impact of System Upgrades
- C. Perform Design Optimization Studies



Gas Flow Considerations

Perform Computation Fluid Dynamic (CFD) Model

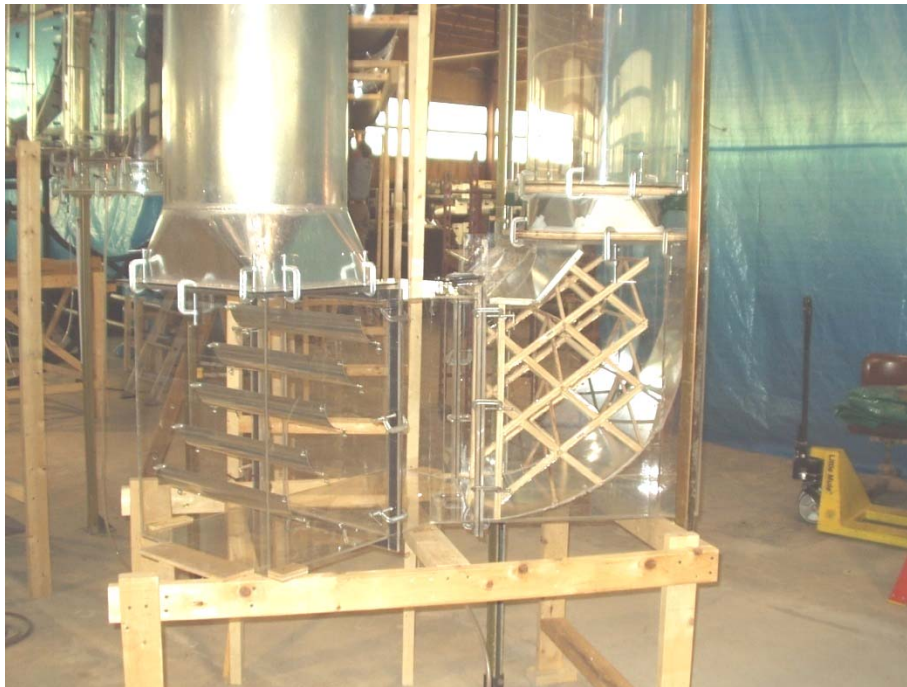
- A. Assess Current System Condition
- B. Assess Impact of System Upgrades
- C. Perform Design Optimization Studies



Gas Flow Considerations

Perform Physical Modeling

- A. Show owner actual simulation of system operation
- B. Change physical and operational parameters on the fly



Gas Flow Considerations

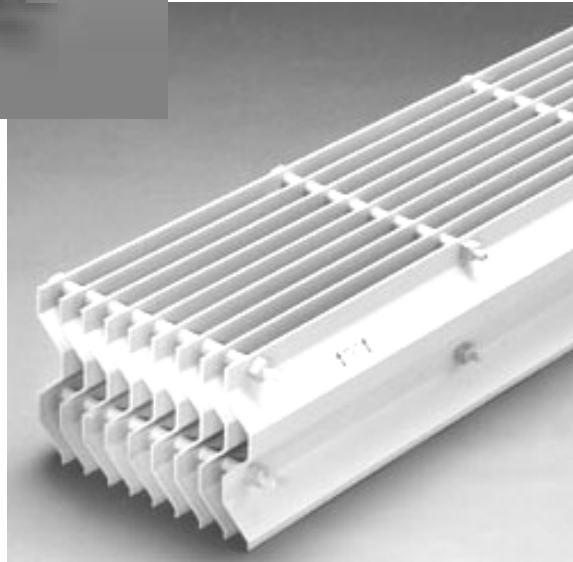
Mist Eliminator Performance

- Absorber gas velocities are generally limited by mist eliminator performance
- Ductwork configuration and gas distribution impact Mist Eliminator performance
- Supersaturated liquid film on mist eliminators can cause precipitation of solids and scaling
- Water quality, spray coverage and optimized sequencing act together to minimize build-ups while keeping emissions low

Gas Flow Considerations



**Mist Eliminator
Improvements**



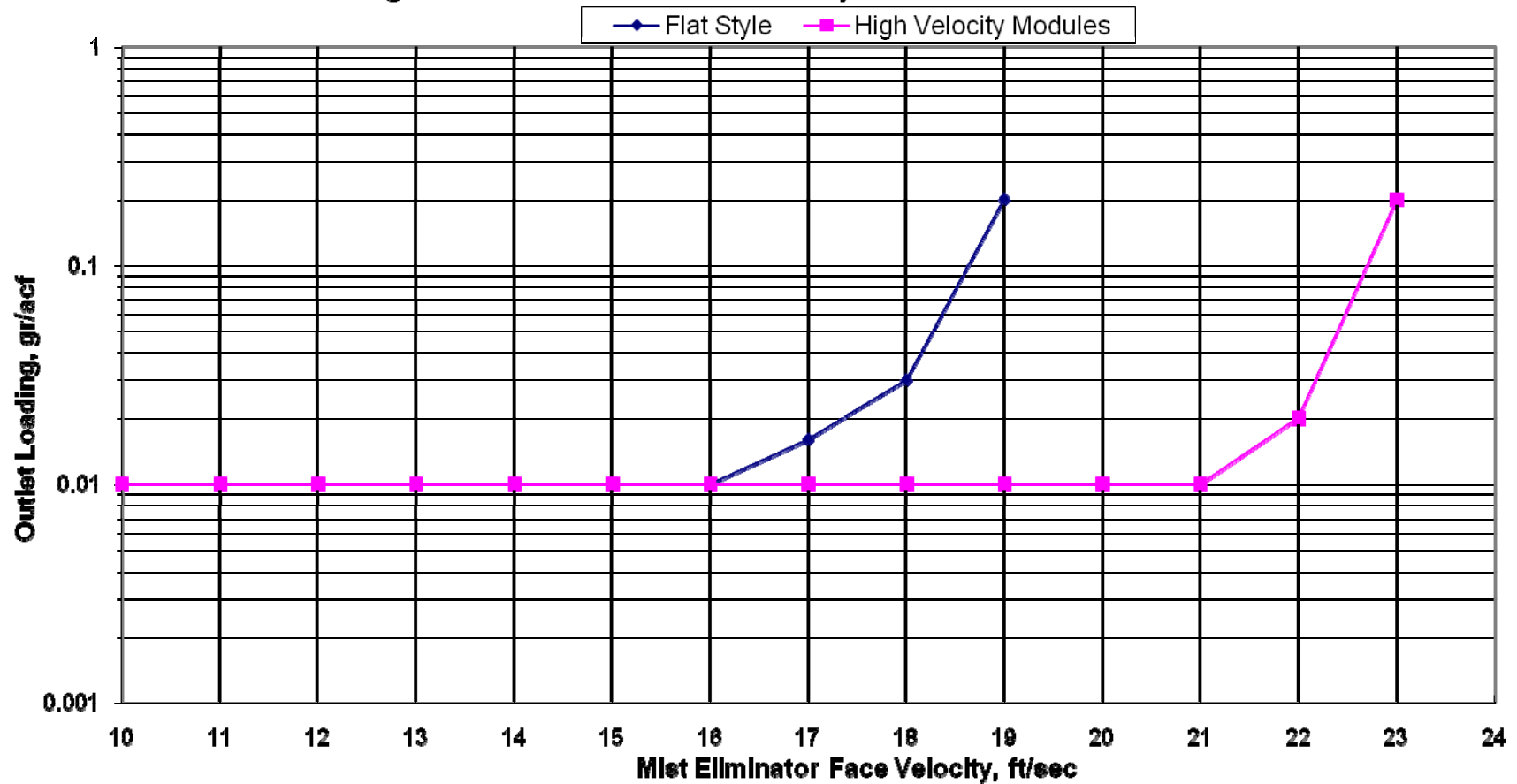
Mist Eliminator Wash System

Gas Flow Considerations

Velocity vs. emissions mist eliminators graph

Potential Performance Enhancement

Mist Eliminator Outlet Loading Vs. Mist Eliminator Face Velocity



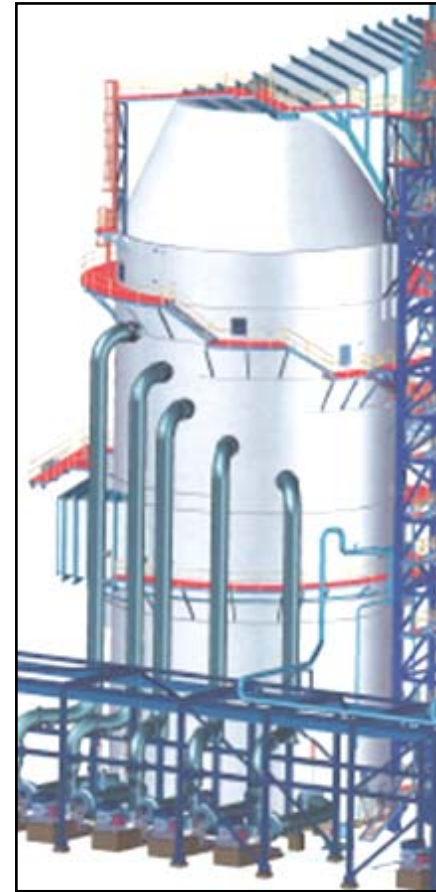
Gas Flow Considerations

Mist Eliminators

- Tower Velocity
- Mist Eliminator Face Velocity – accounts for area of supports & blades
- Mist Eliminator Face Velocity accounting for gas flow RMS

Liquid Side Considerations

- Absorber Recycle Sprays
- Modify Open Spray Towers
- Recycle Pumps / Line Sizes
- Chemistry Process Evaluation
- Reaction Tank Issues
- Bleed Loop / Waste Stream Upgrades
- Reagent System Upgrades

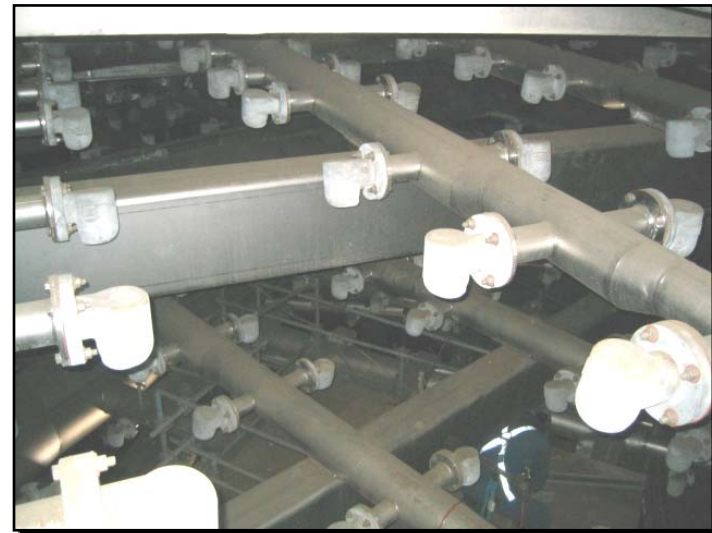


Liquid Side Considerations

Absorber Recycle Sprays

Re-Design / Replacement of Absorber Recycle Sprays

- Improve spray density
- Spray coverage improvement
- Fix impingement problems
- Replace end-of-life headers
- Self Supported headers

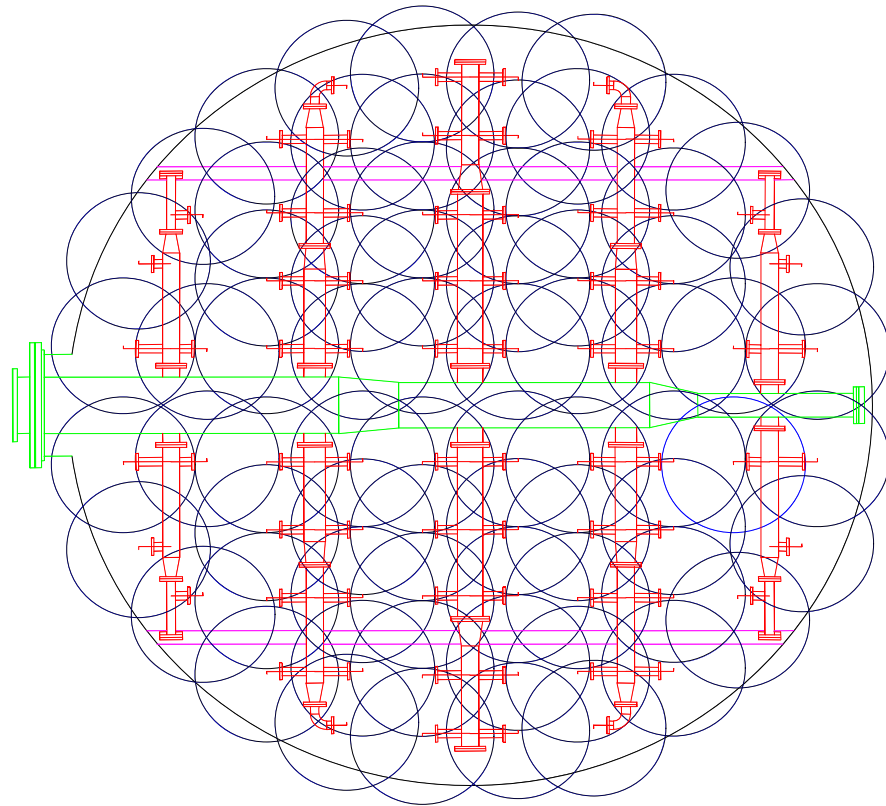


Liquid Side Considerations

Absorber Recycle Sprays

Improve Spray Density/Spray Coverage Improvement

Proper spray pattern design achieves high level of coverage



Liquid Side Considerations

Absorber Recycle Sprays

Self Supported Header



Liquid Side Considerations

Modify Open Spray Towers

- Absorber Liquid Re-distribution Device (ALRD) or tray addition
- Convert packed tower to open spray or tray
- Conversion of Dual Loop Systems to Single-Loop Design
- Structural Assessment

Liquid Side Considerations

Open Spray Tower

Perforated Tray Approach

- Trays provide a bubbling bed of slurry to enhance mass transfer
- Operation of lower L/G saves pump power
- Higher pressure drop costs fan power
- Net power difference (+/-) is site specific and should be determined by specific guarantees
- Operation with proper forced oxidation generally minimizes scaling potential
- Safe use of tray(s) as maintenance platform should be approved by the OEM and confirmed by owner.



Photo courtesy of Reinhold Environmental

Liquid Side Considerations

Open Spray Tower

ALRD Approach

- Developed by MET and patented in 2003
- Mitigate gas “sneakage” along absorber walls
- Re-introduce slurry from walls back into the absorption spray zone
- Increased pressure drop is negligible

United States Patent

Brown et al.

Patent No.: US 6,550,751 B1

Date of Patent: April. 22, 2003

GAS-LIQUID CONTRACTOR WITH LIQUID REDISTRIBUTION DEVICE

Inventors: **Gregory Norman Brown**, Palmyra, PA (US); **Raymond Raulfs Gansley**, Lebanon, PA (US); **Michael Lyn Mengel**, Fredericksburg, PA (US); **Eli Gal**, Lebanon, PA (US)

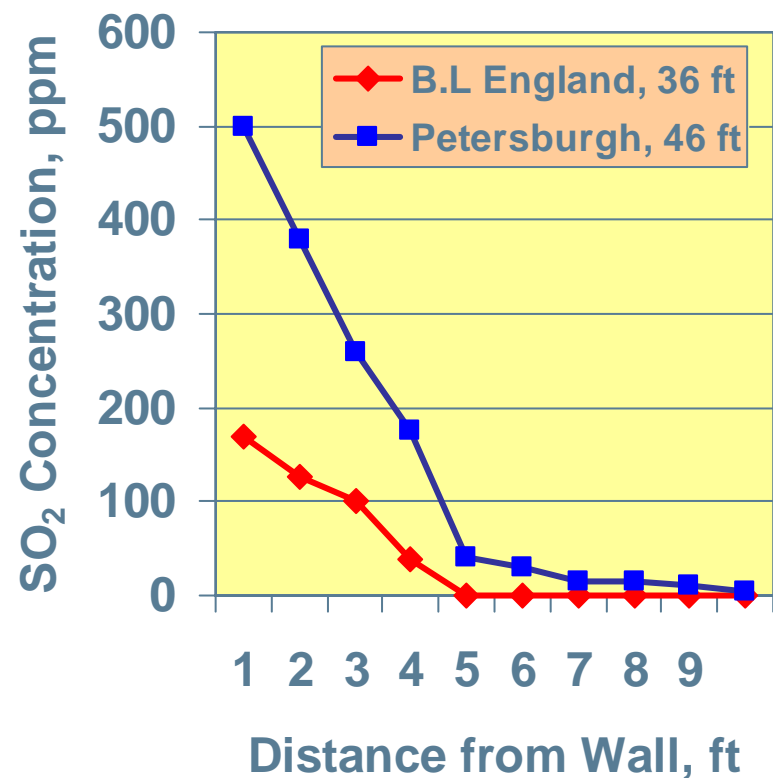
Assignee: **Marsulex Environmental Technologies Corp.**, Lebanon, PA (US)

Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Liquid Side Considerations

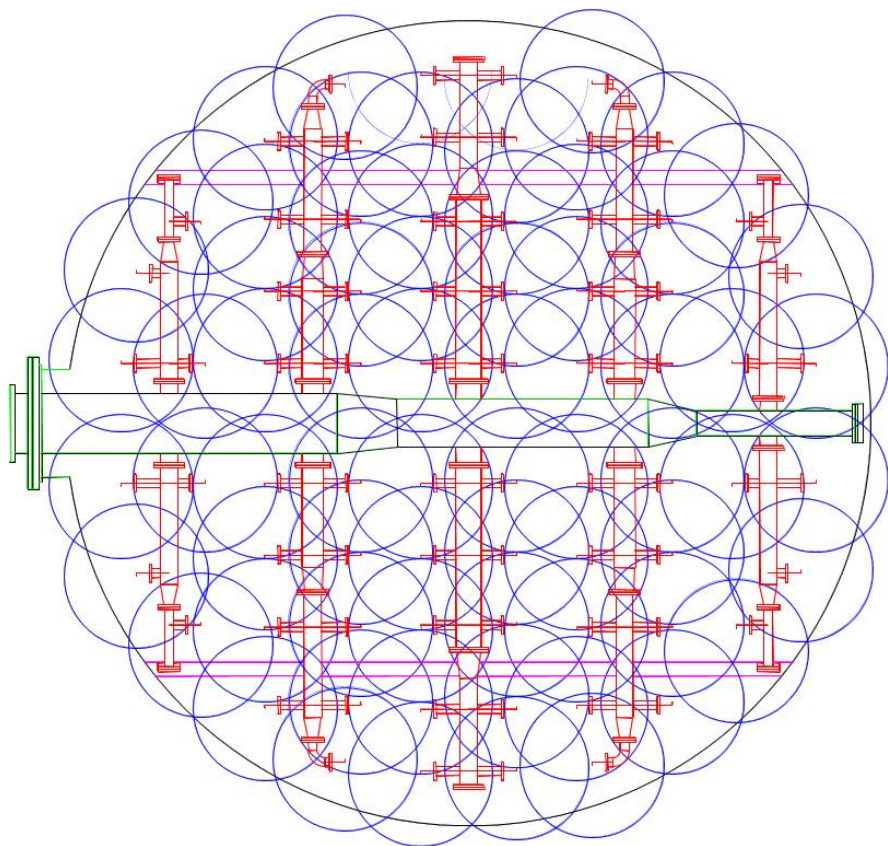
Wall Sneakage Spray Zone Outlet

- **Wall Region**
 - Reduced liquid density
 - Increased gas velocity
 - High SO₂ sneakage
- **Tower Center**
 - Better than required gas/liquid contact
 - SO₂ removed to extinction
- **Overall**
 - Waste of consumables
 - Sets maximum SO₂ removal to less than 100%



Liquid Side Considerations

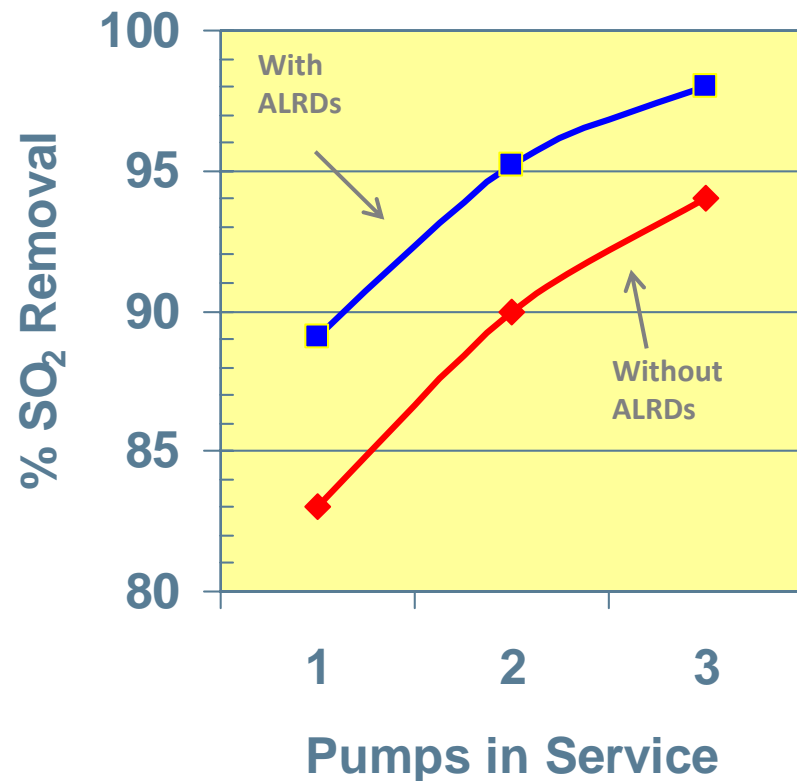
Open Spray Tower



Liquid Side Considerations

ALRDs – How much do they help?

- **Improvement depends on:**
 - Tower diameter
 - Number of shelves in service
- **Improvements:**
 - Take one pump out of service and maintain SO₂ removal
 - Increase SO₂ removal from 94 to 98% with no increase in power consumption
 - Ability to burn higher sulfur coals



Case Study: Demonstrated WFGD Enhancements

ALRD Upgrade

Case Study: USA Mid-Western Power Plant

Original Design

- High sulfur coal fired (2.5 – 3.5% sulfur) utility boiler
- Limestone/gypsum system, single absorber tower
- Four operating recycle spray levels normal + one spare

Upgrade

- Retrofit of Two (2) ALRDs

Case Study: Demonstrated WFGD Enhancements

ALRD Upgrade

Case Study: USA Mid-Western Power Plant (con't)

Results

- With the four normally operating spray levels:
 - SO₂ efficiency increased from 95.7% to 98.7% at 5.6 pH
 - Absorber attained 99.1% efficiency at 5.9 pH
- With only three operating spray levels:
 - SO₂ efficiency increased from 93.8% to 96.1% at 5.6 pH
 - Absorber unit attained 97.1% at 5.9 pH)

Assessment of Absorber Vessel Structural Integrity

- **Step 1:**
Perform Laser Scan
- **Step 2:**
Construct Model from Field Data
- **Step 3:**
Review Results
- **Step 4:**
Perform FEA of Vessel for current configuration and proposed modifications



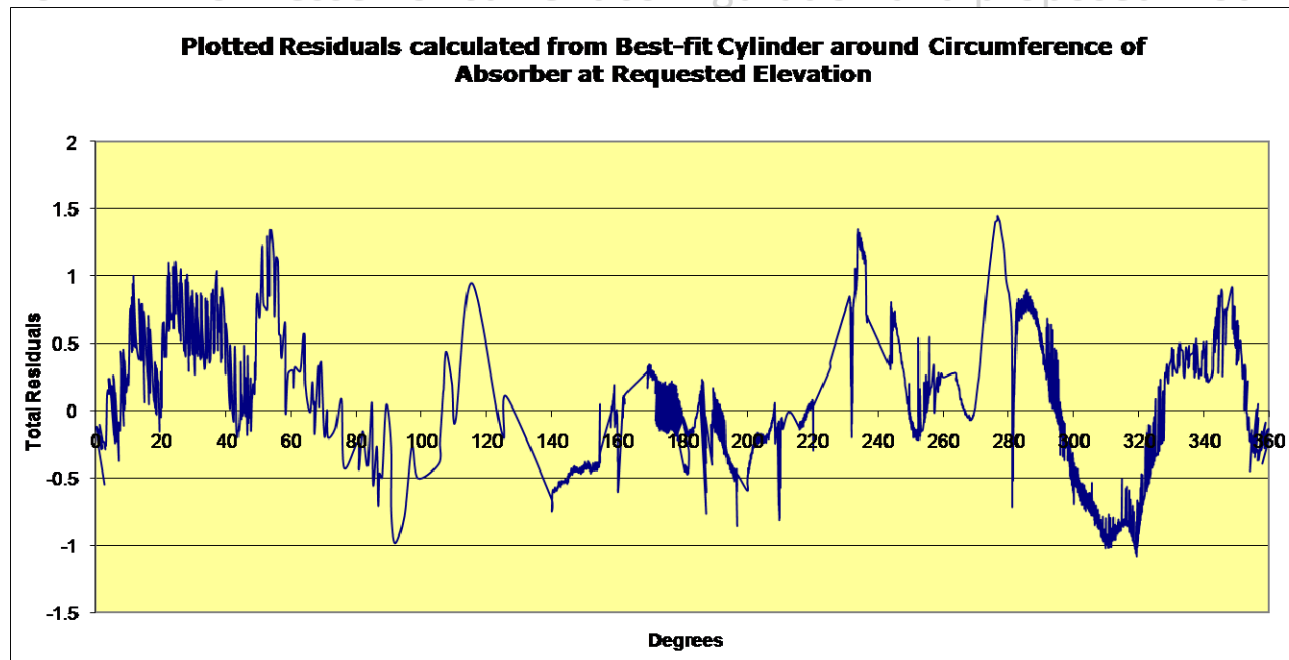
Assessment of Absorber Vessel Structural Integrity

- Step 1:
 - Perform Laser Scan
- **Step 2** – Construct Model from Field Data
 - Resolution to the Millions of Data Points
- Step 3 – Review Results
- Step 4 – Perform FEA of Vessel for current configuration and proposed modifications



Assessment of Absorber Vessel Structural Integrity

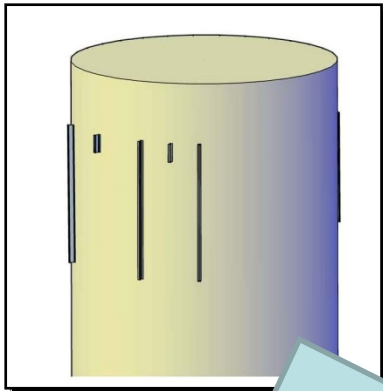
- Step 1 – Perform Laser Scan
- Step 2 – Construct Model from Field Data
- **Step 3** – Review Results
 - Accuracy to +/- 2mm
- Step 4 – Perform FEA of Vessel for current configuration and proposed modifications



Assessment of Absorber Vessel Structural Integrity

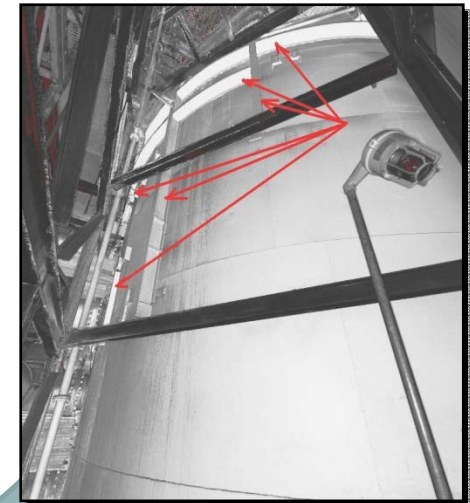


❑ Undocumented additional stiffeners



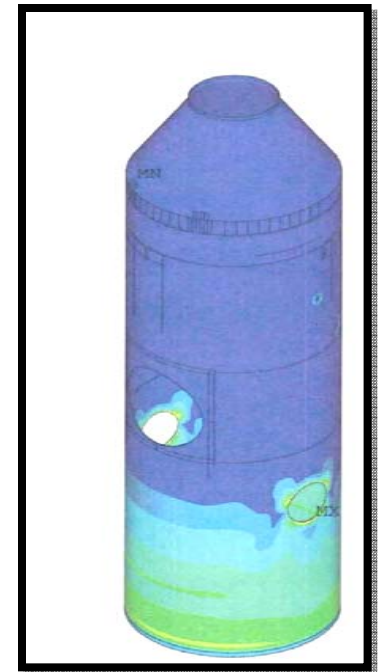
❑ 3D Model w/Stiffeners Accurately Sized and Located

❑ Stiffeners on Laser Scan



Assessment of Absorber Vessel Structural Integrity

- Step 1 – Perform Laser Scan
- Step 2 – Construct Model from Field Data
 - Resolution to the Millions of Data Points
- Step 3 – Review Results
- **Step 4** – Perform FEA of Vessel for current configuration and proposed modifications using:
 - A. Ultrasonic Shell Thickness Measurements
 - B. Laser Scan Results for Deformation and As Built Changes
 - C. Appropriate Load Conditions for Current Design Codes



Liquid Side Considerations

Recycle Pump Sizes

- Motor Change
- Impeller Change
- Gear Box Change
- Pipe Sized Appropriately?



Liquid Side Considerations

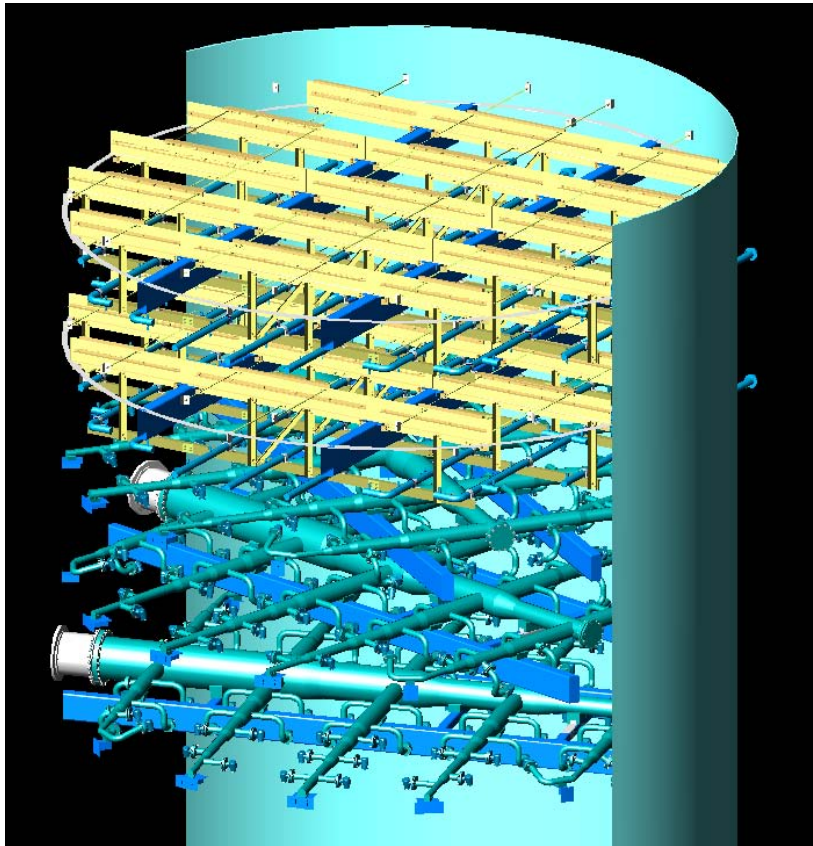
Reaction Tank Issues

- Oxidation System Upgrades
- Gypsum Residence Time
- Recycle Residence Time



Liquid Side Considerations

Chemistry Process Evaluation



- Absorber Stoichiometry
- Slurry Solids
Concentration/Density
- Chloride Concentration
- Water Balance
- Scaling Potential
- Additives

Liquid Side Considerations

Oxidation System Upgrades

- Older style “natural oxidation” increases chances for scaling-type build-ups inside the absorber
- Older style air spargers could plug, causing oxidation problems and need for outage maintenance
- Increased SO₂ removal (overall original design) can tax the oxidation system and increase the chance for sulfite blinding
- Air lance / agitator systems have generally supplanted spargers in modern FGDs and can be retrofitted to older FGDs

Liquid Side Considerations

Oxidation System Upgrades

Agitator with Air Lance in Operation

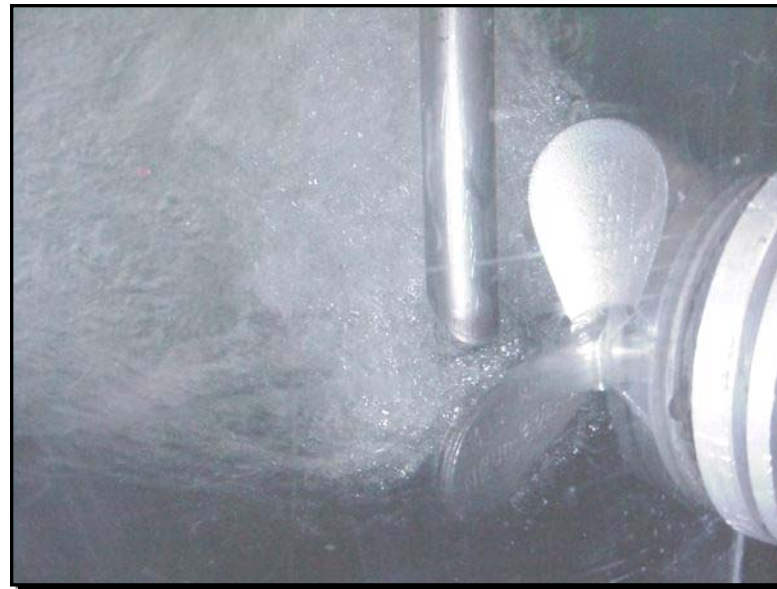
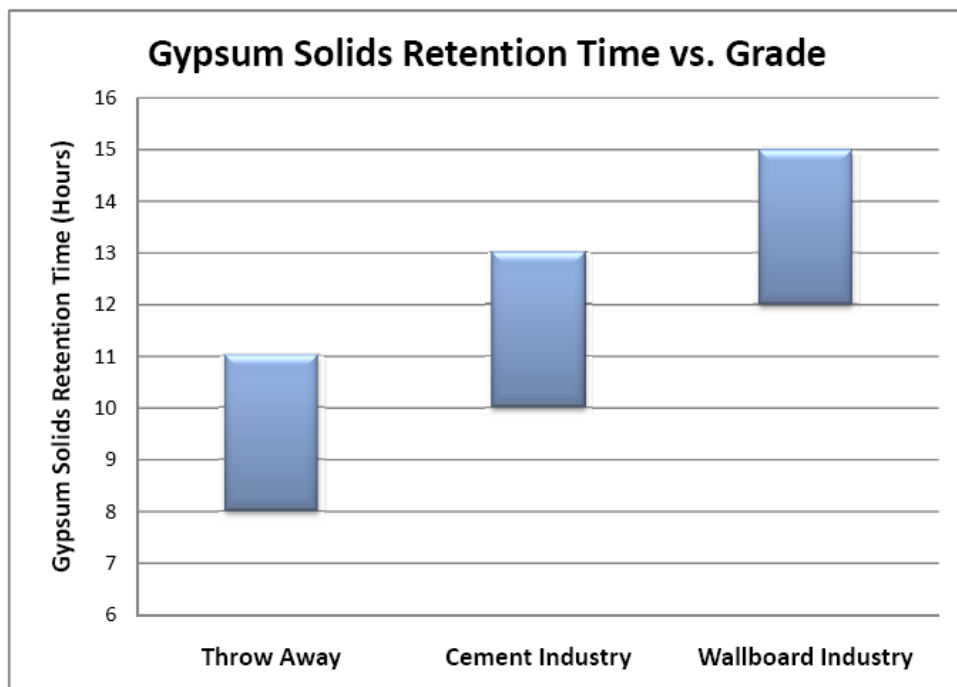


Photo courtesy of Ekato

Liquid Side Considerations

Gypsum Residence Time



Specification for Gypsum for Cement Industry

Analysis:

$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ (Gypsum): 92.0%

Others: 8%

Soluble Impurities:

Chlorides: Less than 2000 ppm

Free Moisture: 10% - 15%

Specification for Gypsum for Wallboard Industry

$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ (Gypsum): > 95 wt%

$\text{CaSO}_3 \cdot \frac{1}{2} \text{H}_2\text{O}$ (Calcium Sulfite): <0.5 wt%

CaCO_3 (Calcium Carbonate) <5.0 wt%

Moisture :<10 wt%

Chloride (Cl): <100ppm

Liquid Side Considerations

Bleed Loop / Waste Stream Upgrades

Hydroclone / Thickener Upgrades



Liquid Side Considerations

Bleed Loop / Waste Stream Upgrades

Vacuum / Disposal Capacity

Rotary Drum Vacuum Filter



Liquid Side Considerations

Reagent System Upgrades

- Increased capacity for higher SO₂ burdens needs to be assessed
- Optimization of limestone grind / classification can be undertaken
- Potential for additives can be evaluated:
 - DBA, Ammonia Salts, Adipic Acid, Formic Acid



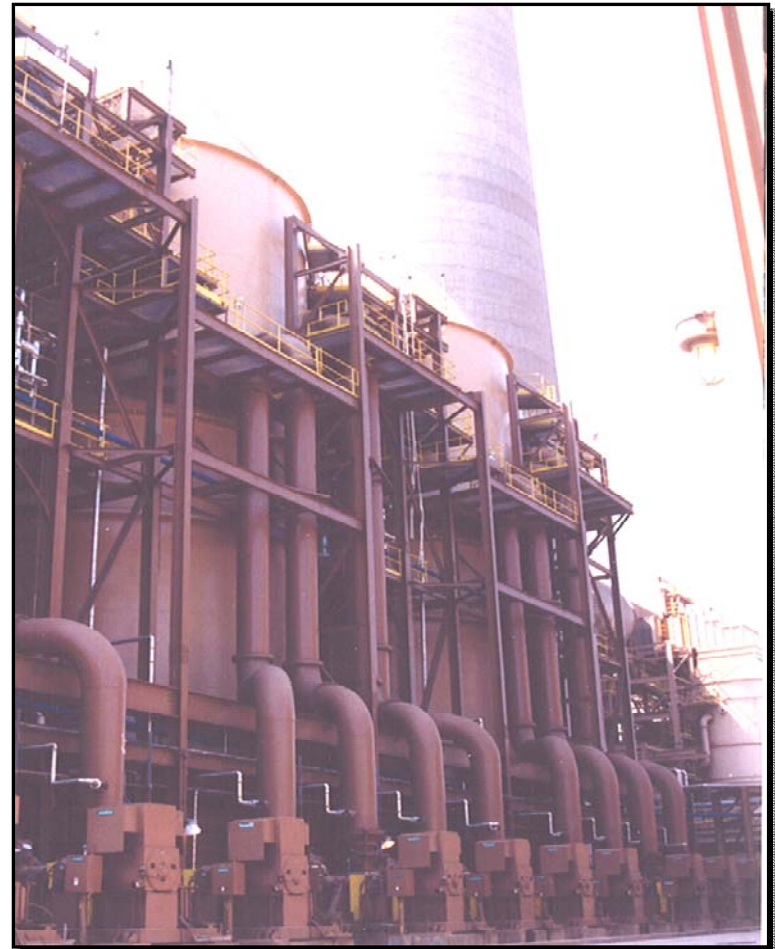
Operation Impact

- Operator Training
- Increased removal efficiency necessitates close observation
- Increase removal efficiency has lower margin of error
- Instrumentation criticality

Liquid Side Considerations

Eastern U.S. Based Utility

- Supplied by GEESI (Marsulex Environmental Technologies) as 3 x 50% modules at 90% SO₂ removal
- Subsequent need to achieve 97% SO₂ removal
- Today operates with spare pump / spray levels in operation to achieve required performance
- Spare tower still available



Case Study

Issue:

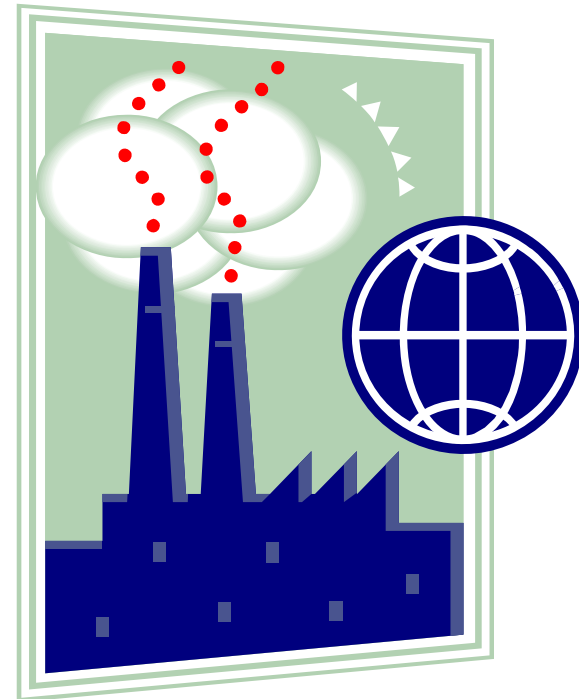
An Eastern utility desired to operate the Unit 1 boiler using a higher sulfur coal / Pet Coke Blend and to conform to increasingly stricter emission guidelines



Case Study

Constraints:

- Maintain the use of only 2 out of 3 absorbers at any time
- No changes to recycle headers
- No changes to recycle spray nozzles



Case Study

Parameters:

- Maximum sulfur content in fuel – 3.36% when blending coal and petcoke
- Chloride in the absorber slurry to not exceed 15, 000 ppm
- Maintain a system Chemistry to allow for continued use by local cement mills
- 97% SO₂ removal efficiency required to meet emission guarantees for worst case
- Limestone grind 90% through 325 mesh

Case Study

Recommendation #1:

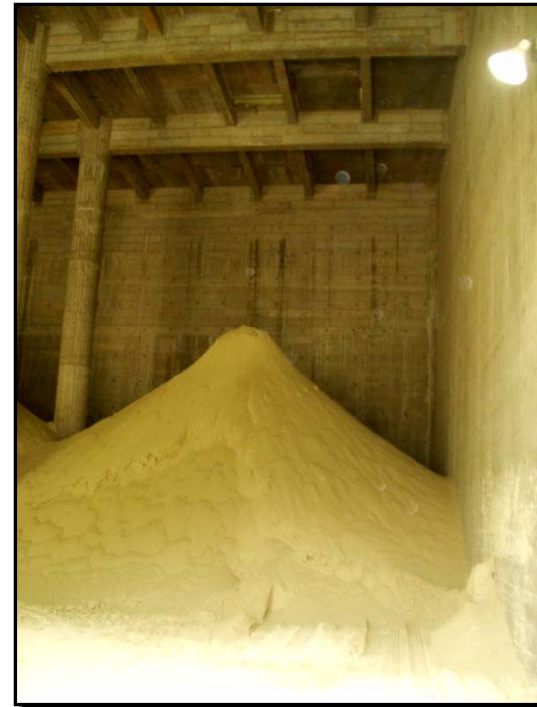
Gear Box changes will be needed to increase pump head for the reduced operating Absorber Liquid level and increased L/G



Case Study

Recommendation #2:

Operate system stoichiometry between 1.08 and 1.10 and increase the suspended solids concentration from 15% to 20% to make available additional calcium carbonate for SO_2 absorption and still maintain the gypsum purity requirement.



Case Study

Recommendation #3:

Install at least two, preferably three, Absorber Liquid Redistribution Devices (ALRDs)



Case Study

Recommendation #4:

- Upgrade Unit 1 Oxidation Air System to ensure complete oxidation of absorber slurry.
- Operate both blowers simultaneously and increase header size



Case Study

Bleed System:

- An increase in SO₂ removal and sulfur loading means a corresponding increase in the bleed to the dewatering systems
- By operating increasing the operational parameter in the absorber vessel to operate at 20% suspended solids only minor changes to the bleed pumps and piping are required

Case Study

Limestone Slurry Feed System:

- Limestone slurry loop piping has adequate capacity for the increased demand
- The feed line and control valve from the loop to the absorber will have to be upgraded



PacifiCorp Energy

Project Facts

FGD System Upgrades

Hunter Units 1 & 2 and Huntington Canyon Unit 1

- Won by MET in sealed bid competition; Owner's Engineer is Sargent & Lundy; 12/09 award
- Design, supply and erection of absorber system modifications, conversion to forced oxidation, civil works, balance of plant upgrades and new reagent preparation system (Hunter Plant)
- Each unit is 430+ MW rated with 4 FGD absorbers (12 total)
- Substantial completion dates:
 - Huntington Unit 1: July 2011
 - Hunter Unit 2: September 2011
 - Hunter 1&2 Reagent Prep System: May 2012
 - Hunter Unit 1: May 2013



Huntington Station and Hunter Station | Utah



PacifiCorp Energy

Lime Based WFGD



Plant:	Hunter	Huntington
MW:	Units 1&2: 430	Unit 1: 445
Fuel:	Coal	Coal
% Sulfur:	1.3%	1.3%
Inlet Gas Volume: (acfm)	2,065,000	1,906,000
Reagent:	Lime	Lime
Absorber Type:	Spray Tower	Spray Tower
Oxidation Mode:	Inhibited- Lances	Inhibited- Lances

Conclusions

Drivers for Upgrades:

- Current Regulations
- Fuel Switching
- Economic Considerations
- Age of Units

Upgrade Considerations:

- Gas Flow
- Liquid Side
- Reagent Changes
- Bleed / Dewatering Systems

