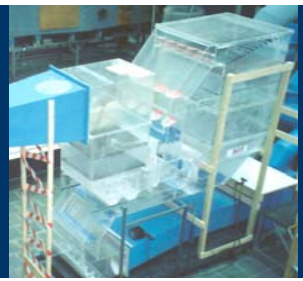
Worldwide Pollution Control Association

ESKOM Scrubber Seminar

April 12th – 13th, 2007

Visit our website at www.wpca.info

Babcock Power Inc.


One Source *Many Solutions* *One Purpose*

WPCA/ESKOM Scrubber Seminar

FGD Design and Operating Criteria

Tony Licata

Babcock Power Environmental Inc.

Wet Scrubbing Challenges

- Liquid to Gas Ratio
- Oxidation
- Chloride Concentration (Blowdown)
- Gypsum
- O&M
- Turndown

Wet FGD Challenges

- Materials of Construction
  - Vessels and headers
- Plugged Nozzles/Lines
- Mist Eliminator Washing
- Filtering Process
- Limestone/lime Storage

Existing Plants Roadmap Performance Targets

Innovations for Existing Plants	2005	2010	2015
Emissions			
SO_2, % removal (emissions, lb SO_2/MMBtu) mg/Nm^3	90 – 95 (0.22 – 0.04) 40-7	98+ (0.09 – 0.009) 16 - 5	99 (0.04 - .01) 7 - 2
NO_X, lb/MMBtu (SCR equipped) mg/Nm^3	0.04 – 0.08 14 – 28	0.02 – 0.04 7 - 14	0.01 – 0.02 3.5 - 7
NO_X, lb/MMBtu (comb. cntls.) mg/Nm^3	0.1 – 0.3 35 - 105	0.06 – 0.1 21 – 35	<0.05 – 0.1 17.5 - 35
Hg removal, %	co-benefits 30 – 90%	65 – 90	80 – 95

Electric Power Research Institute, and the Coal Utilization Research Council

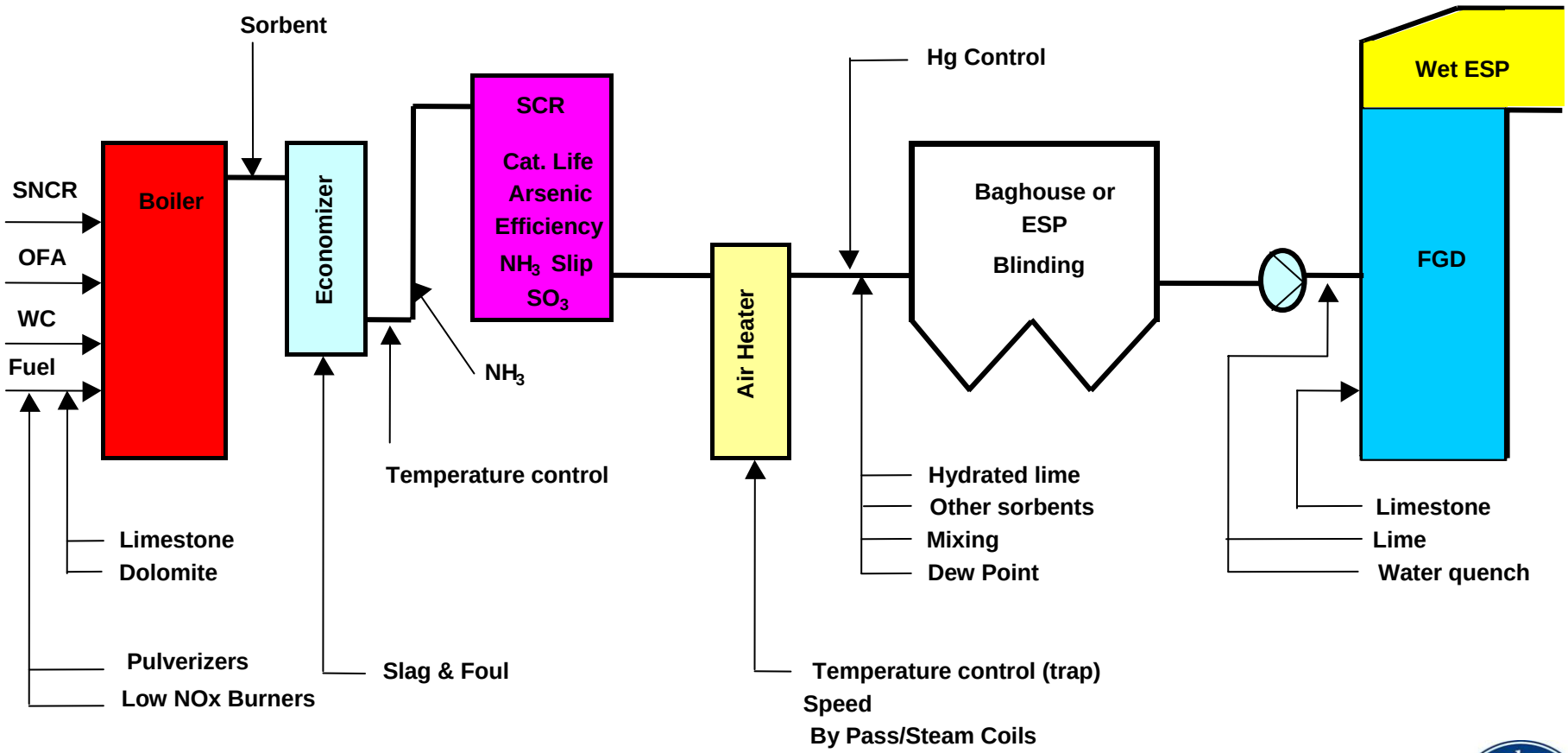
Existing Plants Roadmap Performance Targets

Innovations for Existing Plants	2005	2010	2015
Emissions			
PM emissions, lb/MM Btu mg/Nm^3	0.03 – 0.1 43/144	0.01 – 0.02 14/28	0.01 14
SO_3 emissions, ppmv mg/Nm^3	50 - </=2 14 - 0.56	10 - </=2 2.8 – 0.56	</=2 0.56
Fresh water use, % reduction	baseline	5 – 10	25
By-product utilization, %	39	50	75

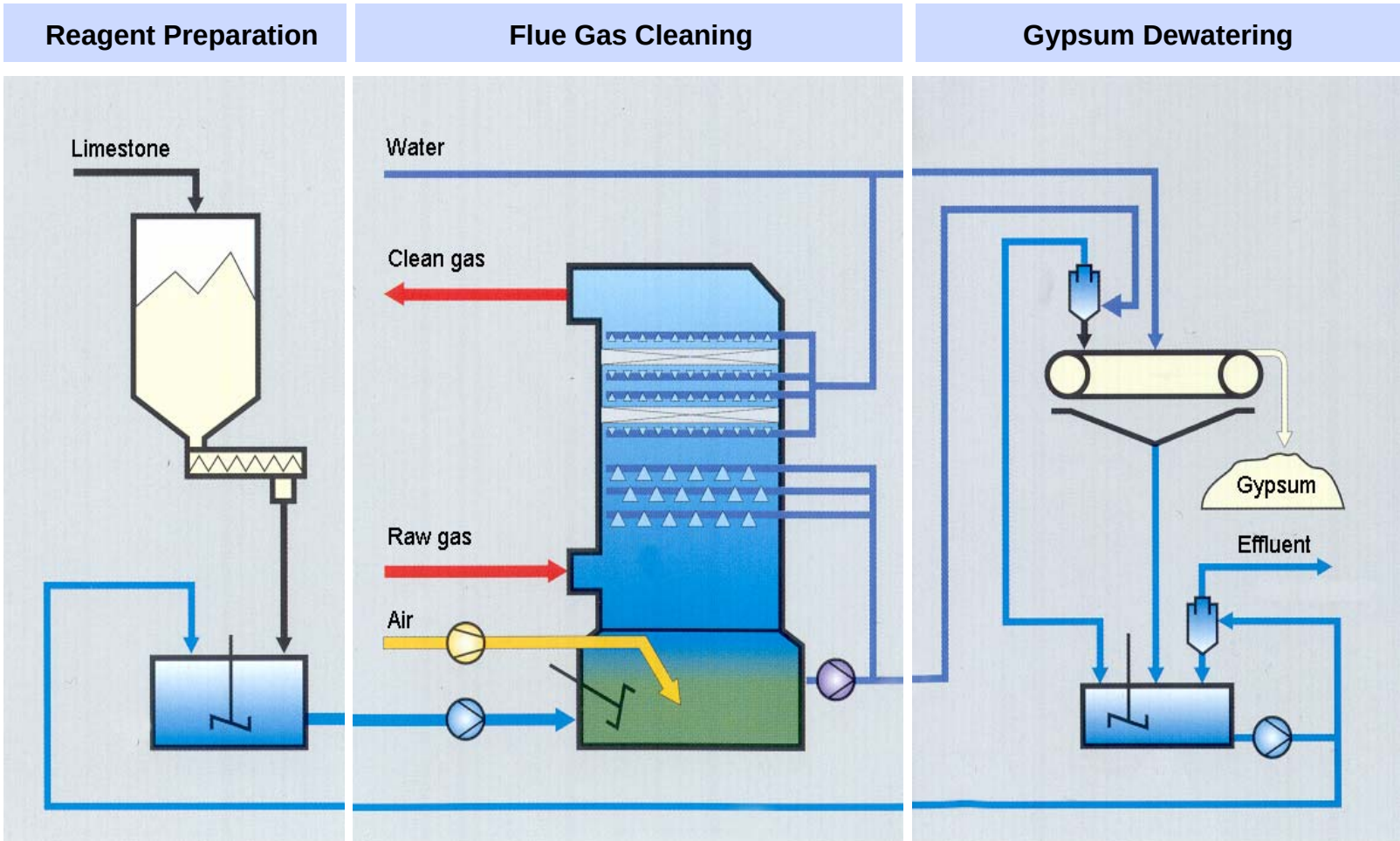
Note targets are dependent on the coal type being used and that the data represents targets for both bituminous and sub-bituminous coals

Electric Power Research Institute, and the Coal Utilization Research Council

Integrated Coal Source to Stack Pollutant Control Solution



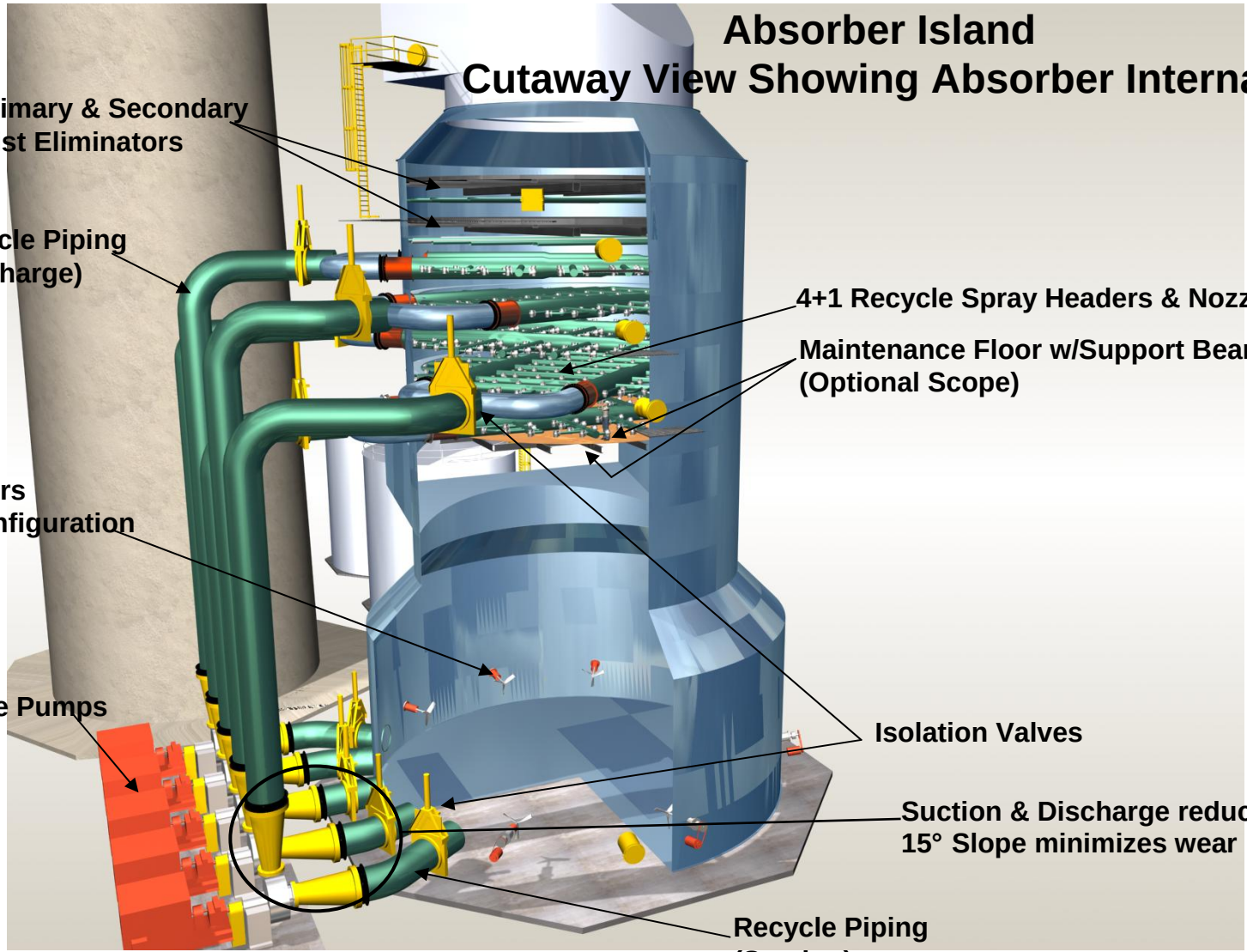
WFGD Process Flow Diagram



Limestone / Gypsum will dominate utility applications

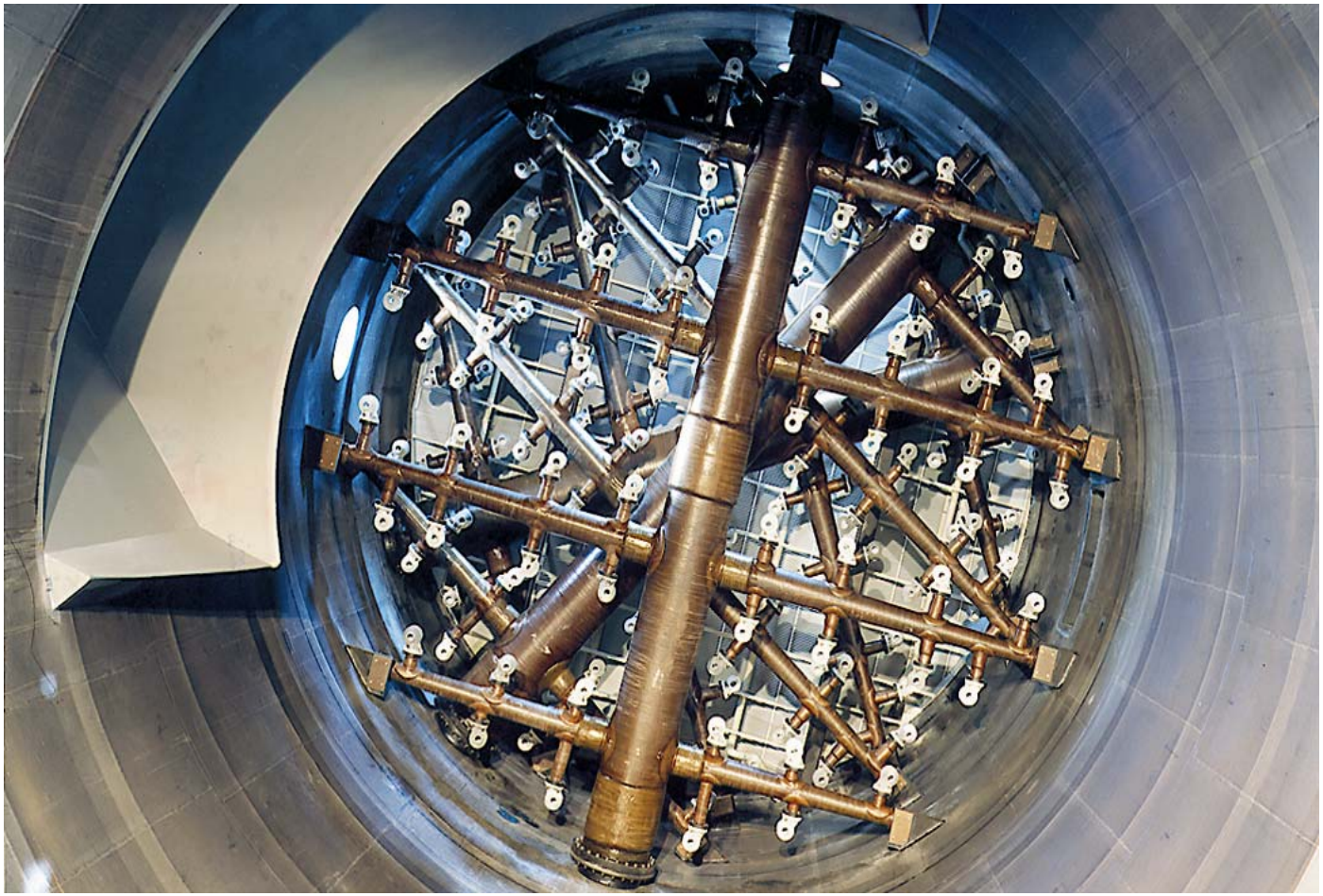
Gypsum loading barge

Absorber Island
Cutaway View Showing Absorber Internals

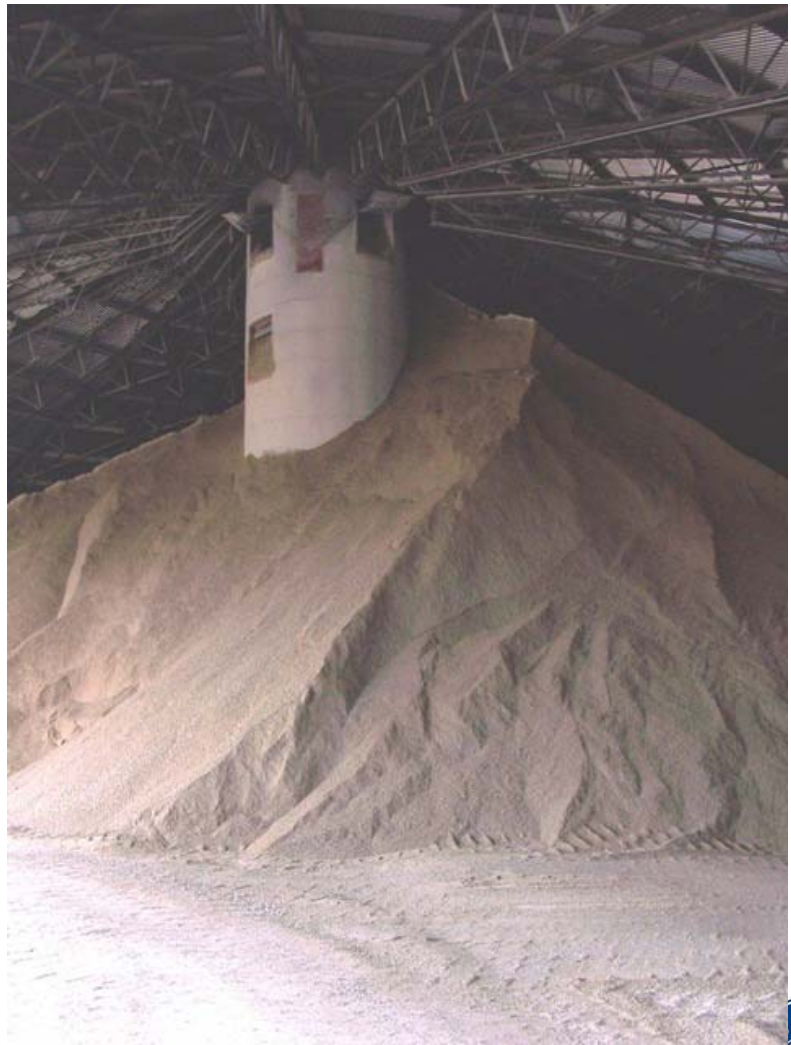


Absorber Internals

FGD Absorber Internals



Weather Protected Limestone Storage and Feeding



Enclosed Ball Mill for Sound Protection and Maintenance in Cold Climate

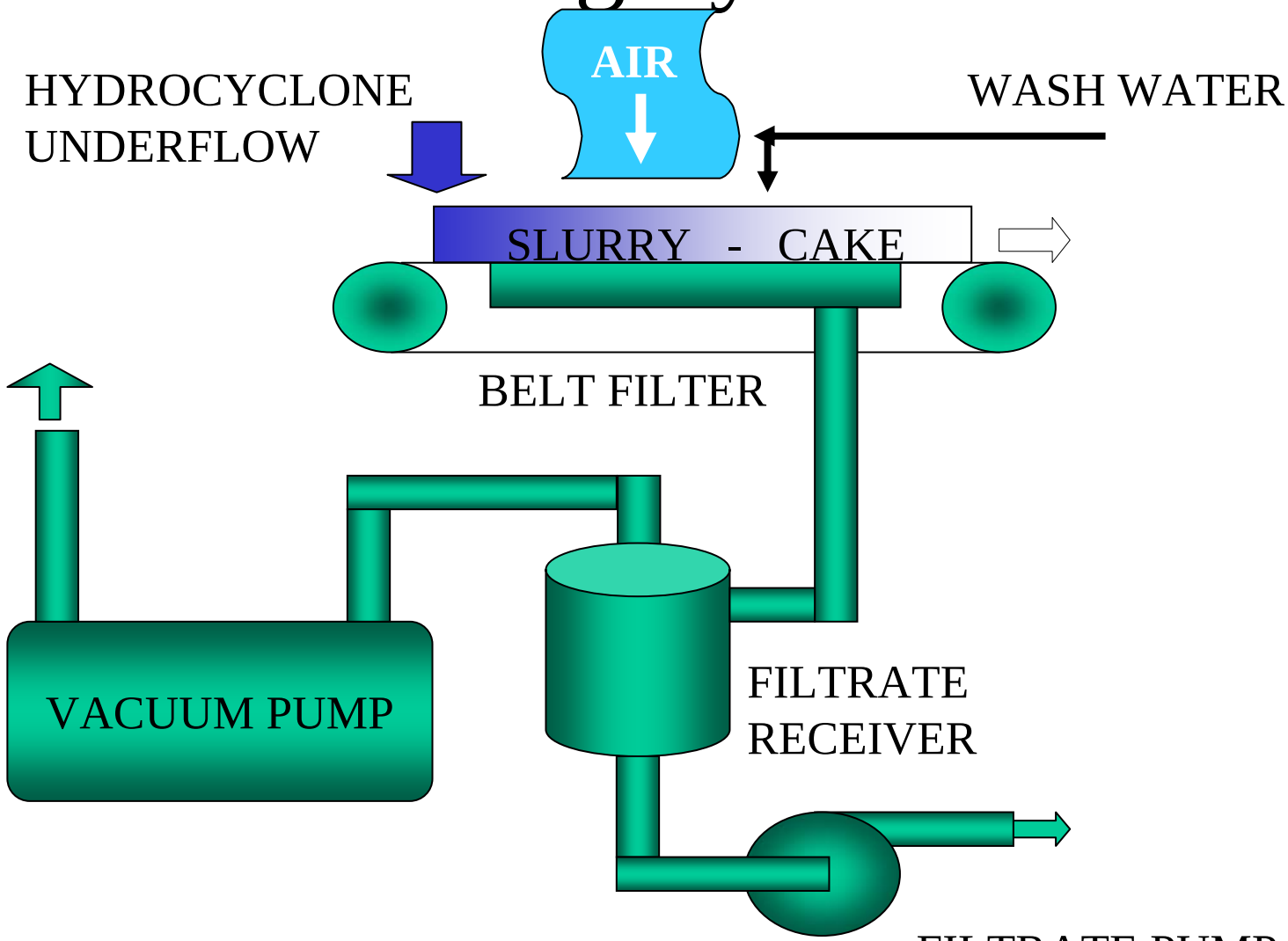
Outdoor Ball Mill

Warm Climate

Maintenance Crane

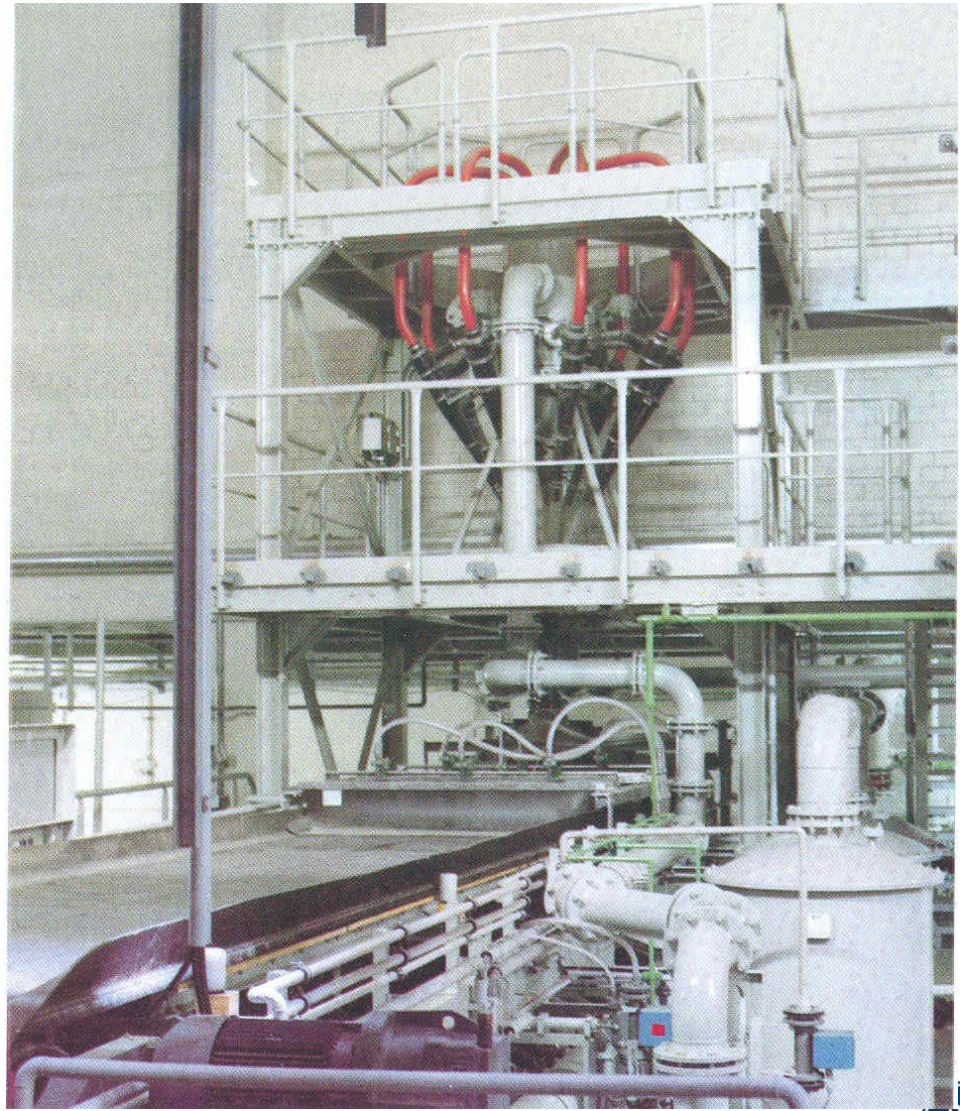
Oxidation Air Blowers in Sound Enclosure

Dewatering System



Gypsum Dewatering

Hydrocyclone
&
Belt Filter
Arrangement



Power Optimization

Design Influence

- Recycle Pumps
- Fans – Gas Side DP
- Oxidation Air Blowers
- Limestone Grinding Mills

Operational Influence

- On-line Optimization
- Automatic and in Real Time

Power Optimization
Oxidation & Agitation

- **Tank Sizing**
  - **Limestone Dissolution**
  - **Oxidation**
    - **Mixing**
    - **Residence Time**
  - **Reaction Completion**
    - **De-supersaturation**
  - **Gypsum Crystal Growth**
    - **Size**
    - **Shape**
- **On-line Monitoring**

Power vs. SO_2 Removal

750 MW East. Bituminous Coal

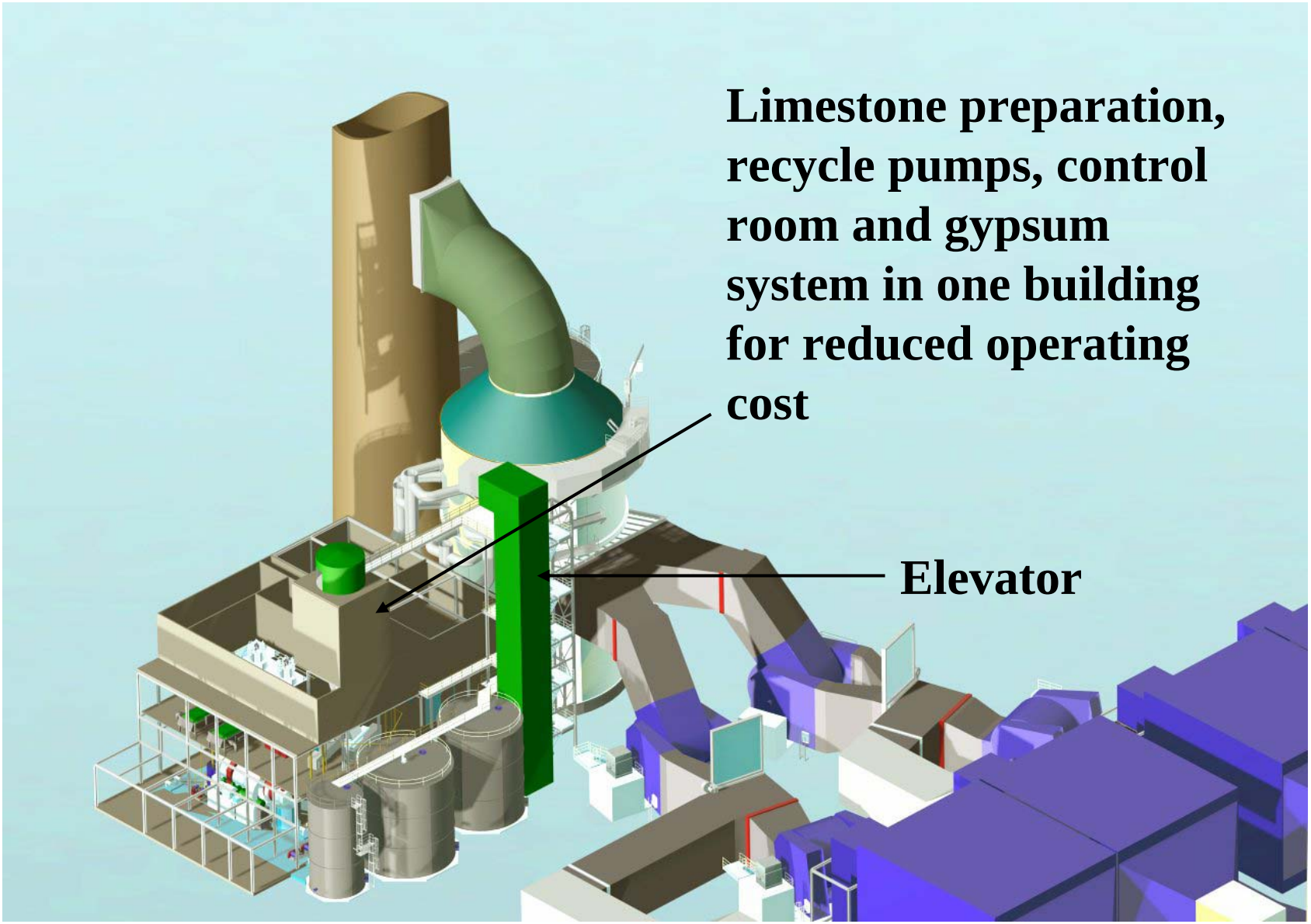
Wet FGD Power Usage

		SO_2 Removal		
		95%	97%	99%
Booster Fan	kW	4,253	4,593	5,303
Recycle Pumps	kW	4,160	4,593	6,961
Oxidation Air Blowers	kW	2,315	2,556	3,500
Ball Mills	kW	1,614	1,648	1,682
Others	kW	2,660	2,710	2,772
total	kW	14,572	16,100	20,218

Operation and Maintenance

O & M Criteria

- **Safety**
- Balance between initial capital cost vs. long-term operating cost
- Plant availability/redundancy
- Operating economics
  - Elevators vs. stairs
  - Weather encloses
- Wash down/Cleaning
  - Drains/pits/pumps
- All in one building



Isolation Valves for Pump Maintenance

All pumps in straight line/overhead cranes

Note wide maintenance aisles

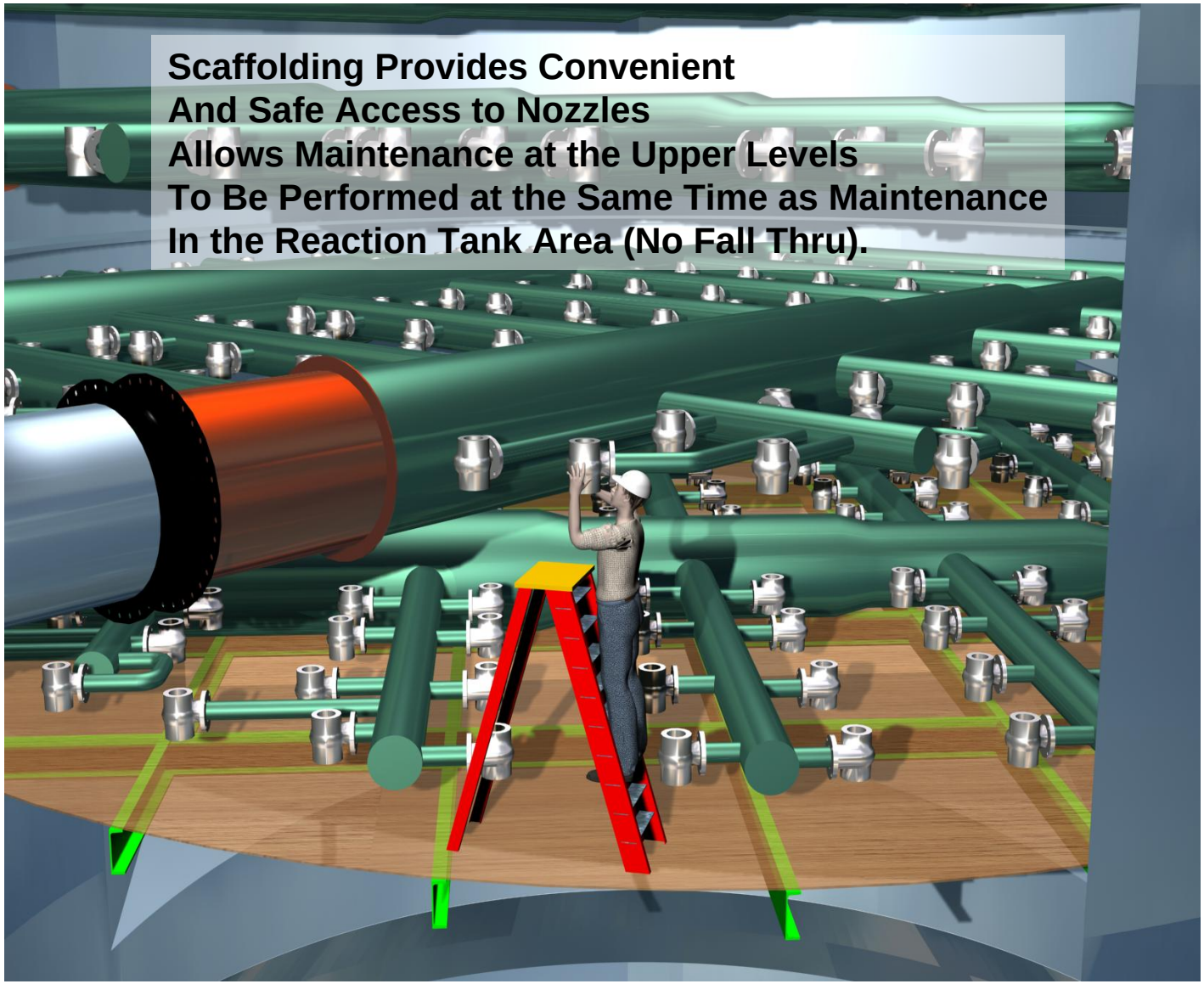
Floor drains

Overhead crane for maintenance

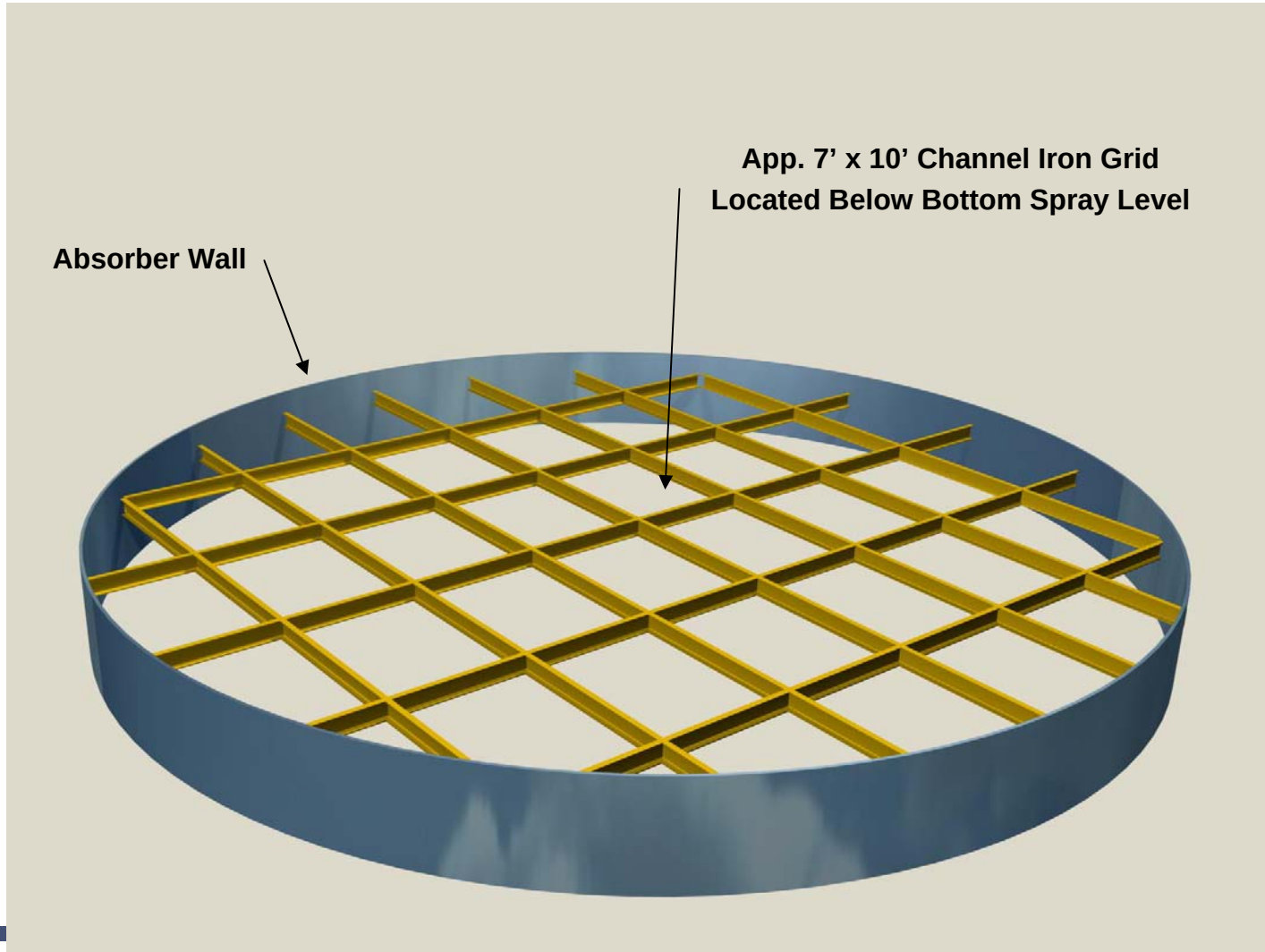
Room between pumps for forklift

Overhead cranes

Recycle pump screens to prevent pump wear and nozzle plugging



Maintenance Support Grid



Operational WGFD Testing Requirements

	Frequency of sampling	pH	Density	Wt % of solids	Chemical composition of solids SO_4^{-2} SO_3^{-2} CO_3^{-2} Inert	Particle size Distr.	Cl- Content
Slurry recycle	**1x per day**	**X**	**X**	**X**	**X**	**X (2/week)**	**X**
Gypsum Slurry	**1x per week**		**X**	**X**	**X**	**X**	**--**
Gypsum	**1x per week**				**X**	**X**	**X**
Limestone Slurry	**1x per week**	**X**	**X**	**X**	**X**	**X**	**X**
Limestone	**Weekly composite**				**X**		
Ball Mill Hydrocyclones						**X**	
Make Up Water	**1x per week**	**X**					**X**
Waste Water	**1x per week**	**X**		**X**			**X**

Operational WGFD Testing Requirements

Test Description	Test Method
pH	EPRI -C1
Density	EPRI -D2
Wt % of Solids	EPRI -F3
Chemical Composition-Sulfate	EPRI -L2
Chemical Composition-Sulfite	EPRI -M1
Chemical Composition-Carbonate	EPRI -N3
Particle Size	EPRI -G1
Crystal Water	ASTM C471M
Residual Moisture	ASTM C471M
Chloride	EPRI -I3

Operational WGFD Testing Manpower

- Man-hours per absorber 14.5 hours / week
- Man-hours plant common systems
  - Reagent system 15.5 hours / week
  - Water system 4.5 hours / week
  - Gypsum byproduct 4 hours / week
- Man-hour estimate 2 absorbers and common systems 53 hours
- Man-hour estimate 2 absorbers and common systems 2756 hours

Periodic Mechanical Inspection

- Pumps – Check
  - Oil level
  - Seal leakage
  - High vibration
  - Belt tension
  - Bearing temperature
  - Alignment
- Agitators – Check
  - Oil level
  - High vibration
  - Gland seal water leakage
- Strainers
  - Differential pressure each shift, clean if high

Periodic Electrical Inspection

- Motors – Check
  - Bearing temperature
  - Insulation resistance
  - Bearing vibration
  - Brush wear
  - Slip ring roughness
  - Motor heater current
  - Clean parts of carbon dust
- Electrical
  - Annual inspection or per manufactures instructions
- Relays
  - Differential pressure each shift, clean if high
- Instrumentation
  - Per manufactures instructions

Periodic Maintenance Manpower

- Man-hours per absorber 20 hours / week
- Man-hours plant common systems
  - Reagent system 20 hours / week
  - Assist with Operational Testing 20 hours / week
- Man-hour estimate 2 absorbers and common systems 80 hours
- Man-hour estimate 2 absorbers and common systems 4160 hours

Operation and Maintenance Manpower

- WFGD Operator, current control room operator from each unit will monitor and control
- Assistant WFGD Operator, one required for plant, perform WFGD operational testing
- Maintenance Mechanic, two required for plant, perform periodic maintenance and assist with testing

Scheduled Outage Inspection

- Absorber Tank
  - Inspect for corrosion, scale and deposits
  - Remove loose material
  - Map location of deposits
  - Repair lining as needed
- Spray Headers and Nozzles
  - Check spray nozzles for plugging and map
  - Clean or replace nozzles as necessary
  - Check headers for erosion
- Mist Eliminators
  - Check for damage or deposits
  - Check wash system for valve function and coverage
- Reagent Preparation
  - Inspect and repair in accordance with manufactures' instructions

Outage and Maintenance Costs

- Estimated outage (3 yr) cost $250,000 / absorber including
  - Absorber scaffolding
  - Sump cleaning
  - Absorber vessel and header repairs
- Estimated yearly maintenance cost $150,000 / absorber including
  - Agitator parts
  - Recycle pump rebuilds
  - Misc. pump rebuilds

Unique Process Features

- Bi-Directional Spray Nozzles
- Wall Rings
- Advanced Hydraulic Spray Header Design
- Maintenance Platforms

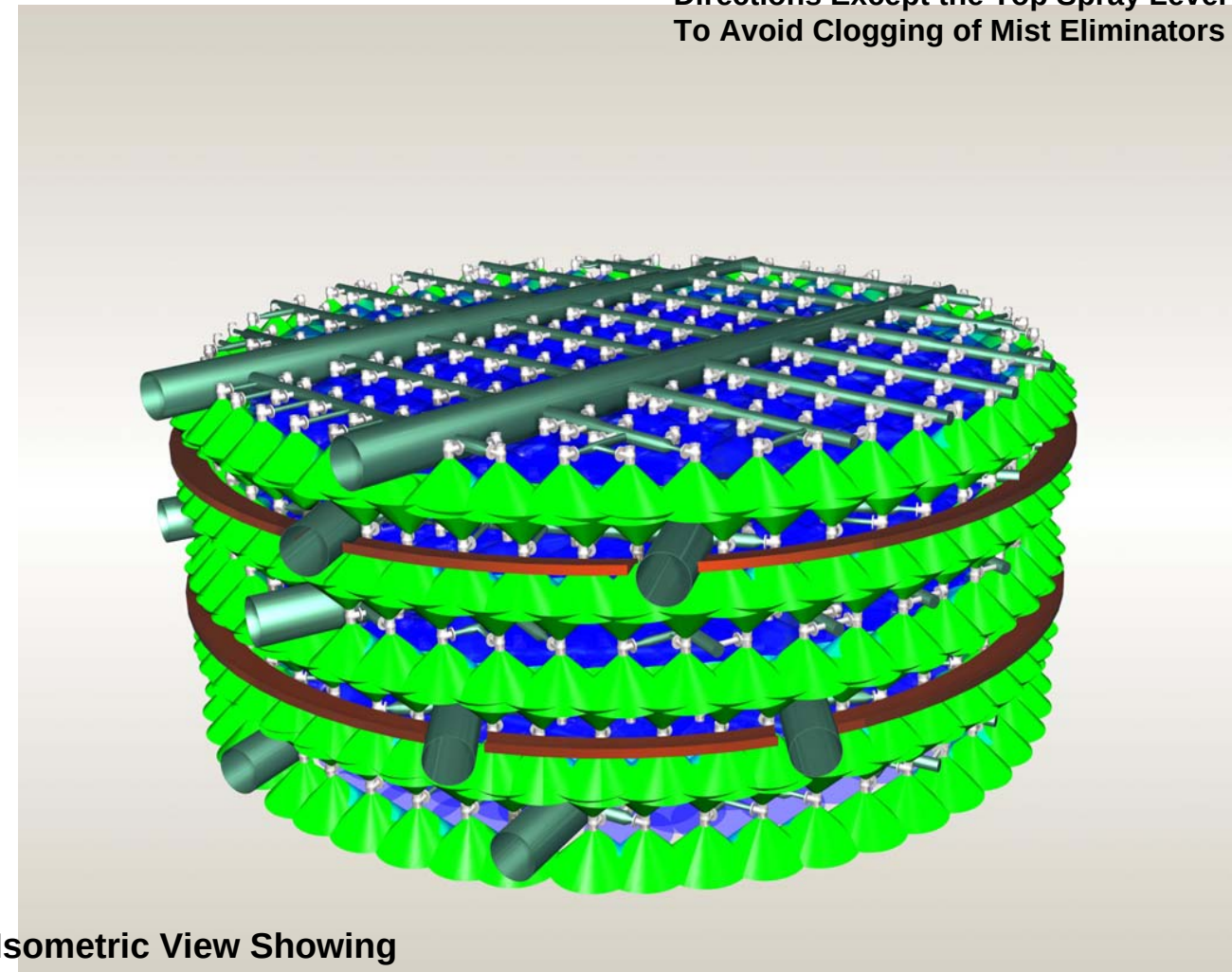
Bi- Directional Spray Nozzles

- Upward Spray Energy Lowers Pressure
- Number of Liquid Orifices Doubles
  - Smaller Droplet Size at Same Pump Power
- Intersections of Spray - Greatly increased
  - Small ‘mist’ droplets are generated
    - Increased surface to mass ratio
  - Droplets mixed and reformed
    - Increased mass transfer at gas-liquid interface

Characterizing Spray Nozzle Flow

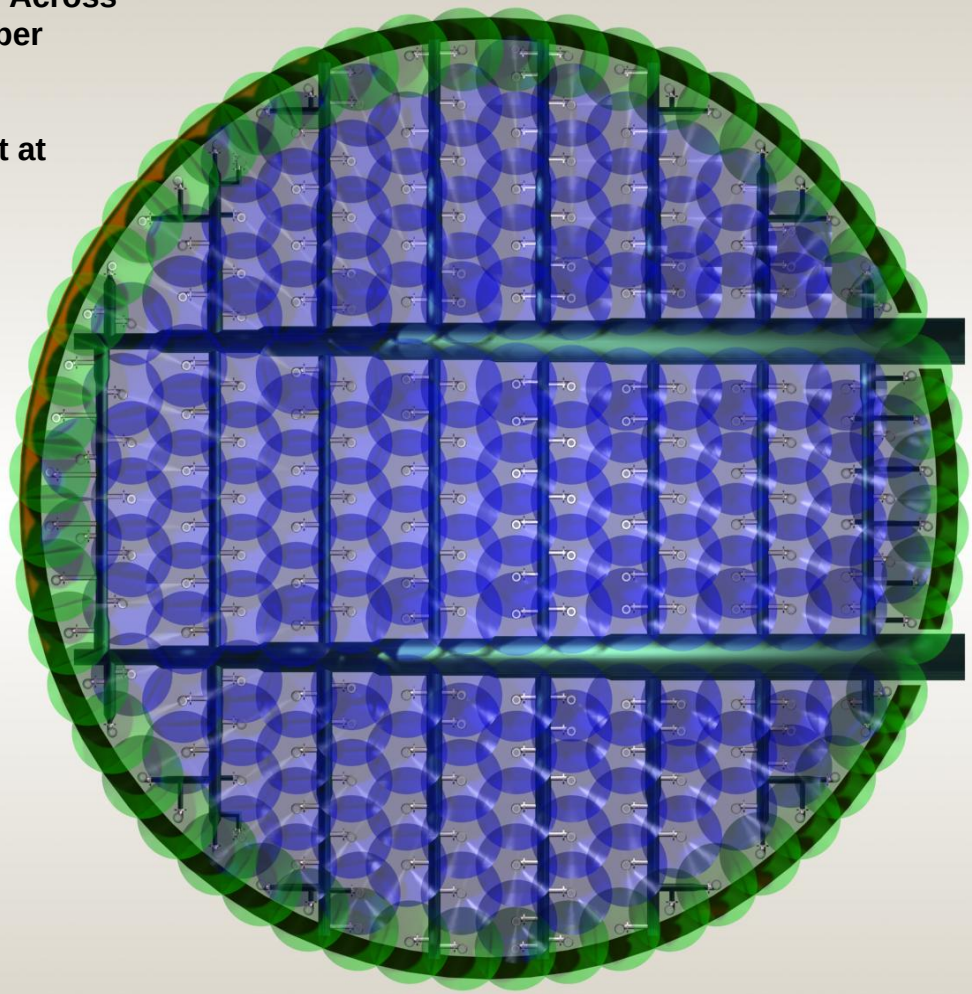
- Bi-Directional
- Hollow Cone
- Wide Angle
- Low Liquid Pressure
- Small Droplets

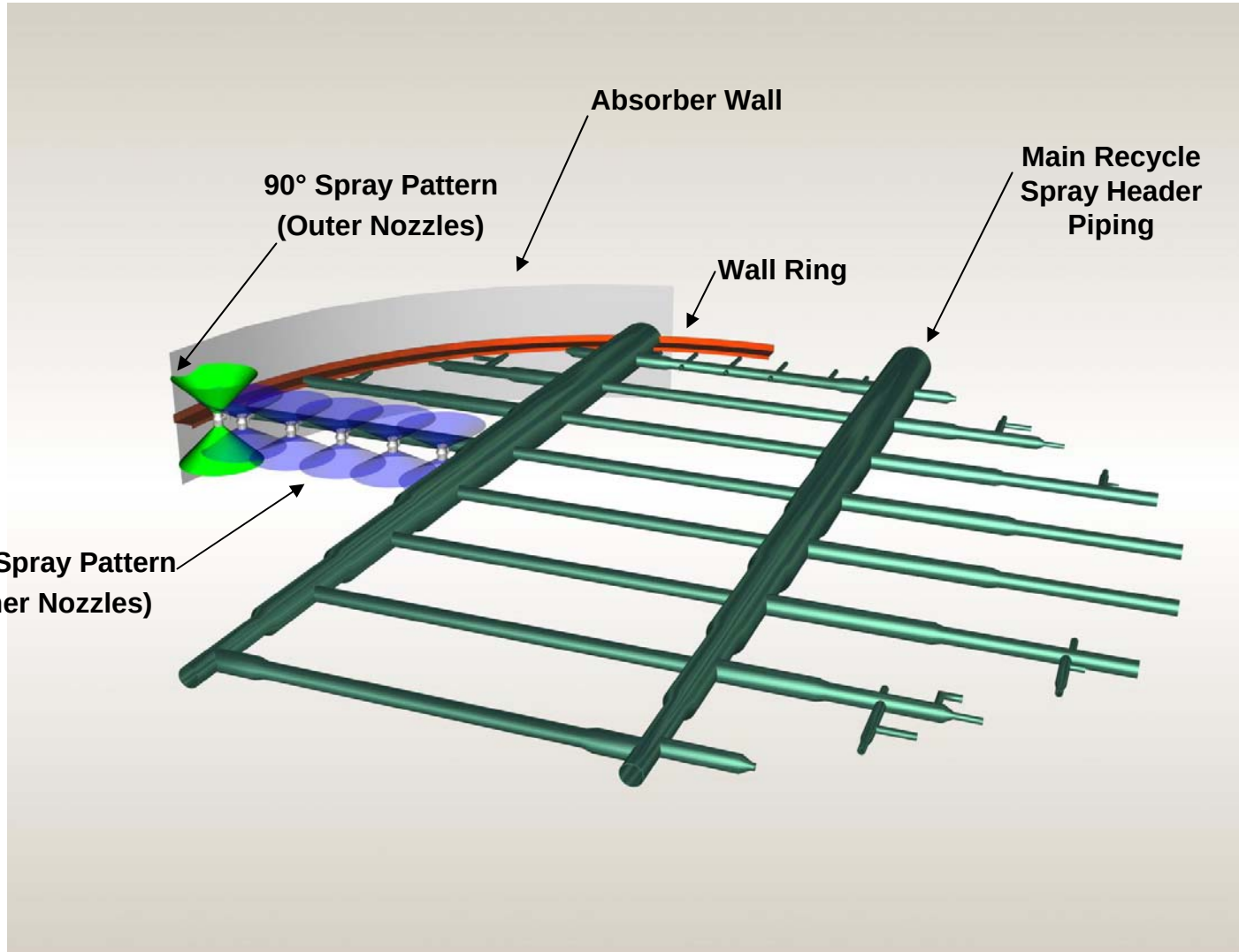
Note: All Elevations Spray In 2 Directions Except the Top Spray Level To Avoid Clogging of Mist Eliminators

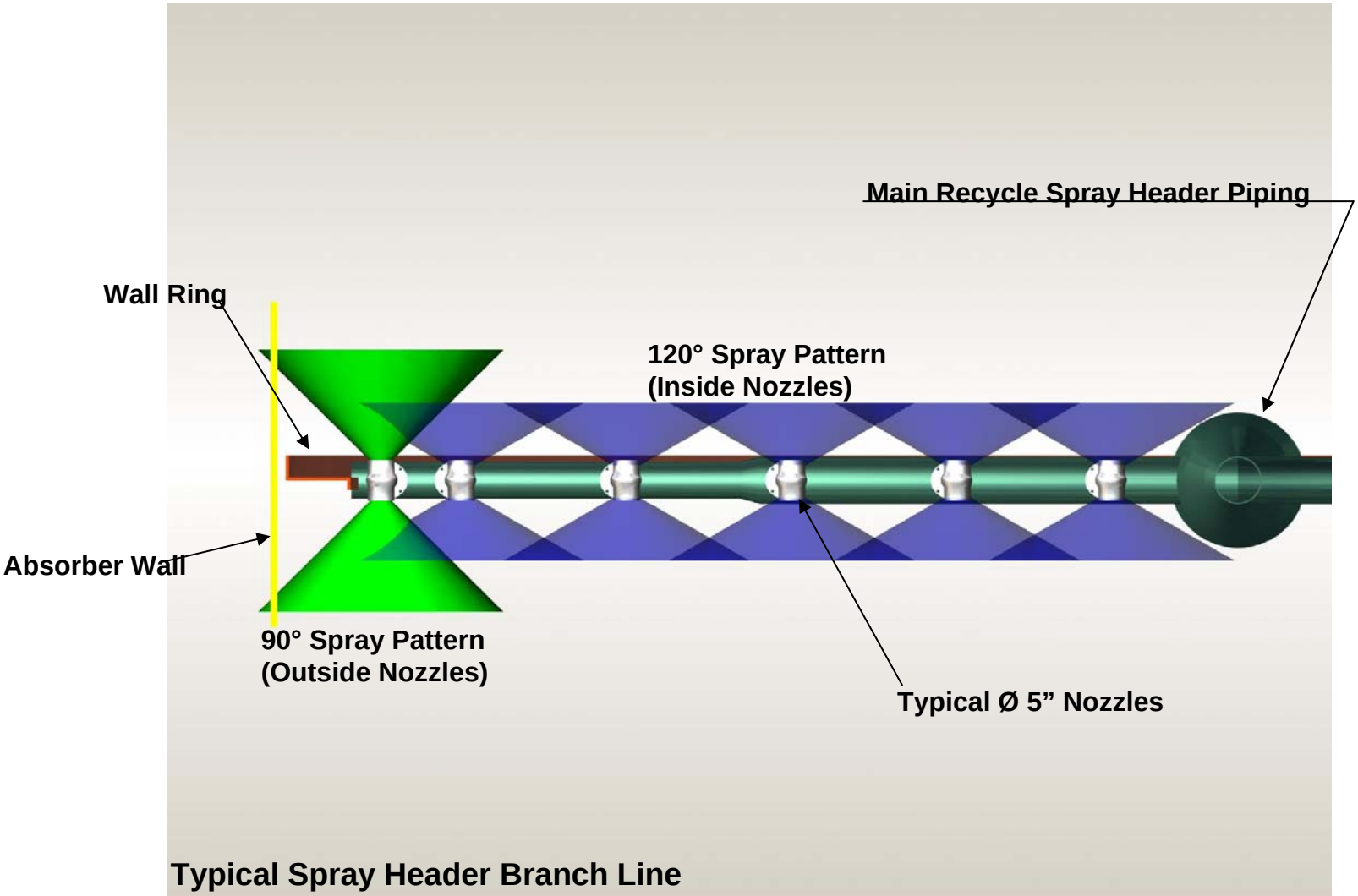


Isometric View Showing Spray Pattern Across Five Levels

- **Spray Nozzles Arranged**
  - **To Provide Full Coverage Across The Section of the Absorber**
- **Outer Nozzles Arranged to Ensure Maximum Coverage And Reduce Impingement at The Absorber Wall**



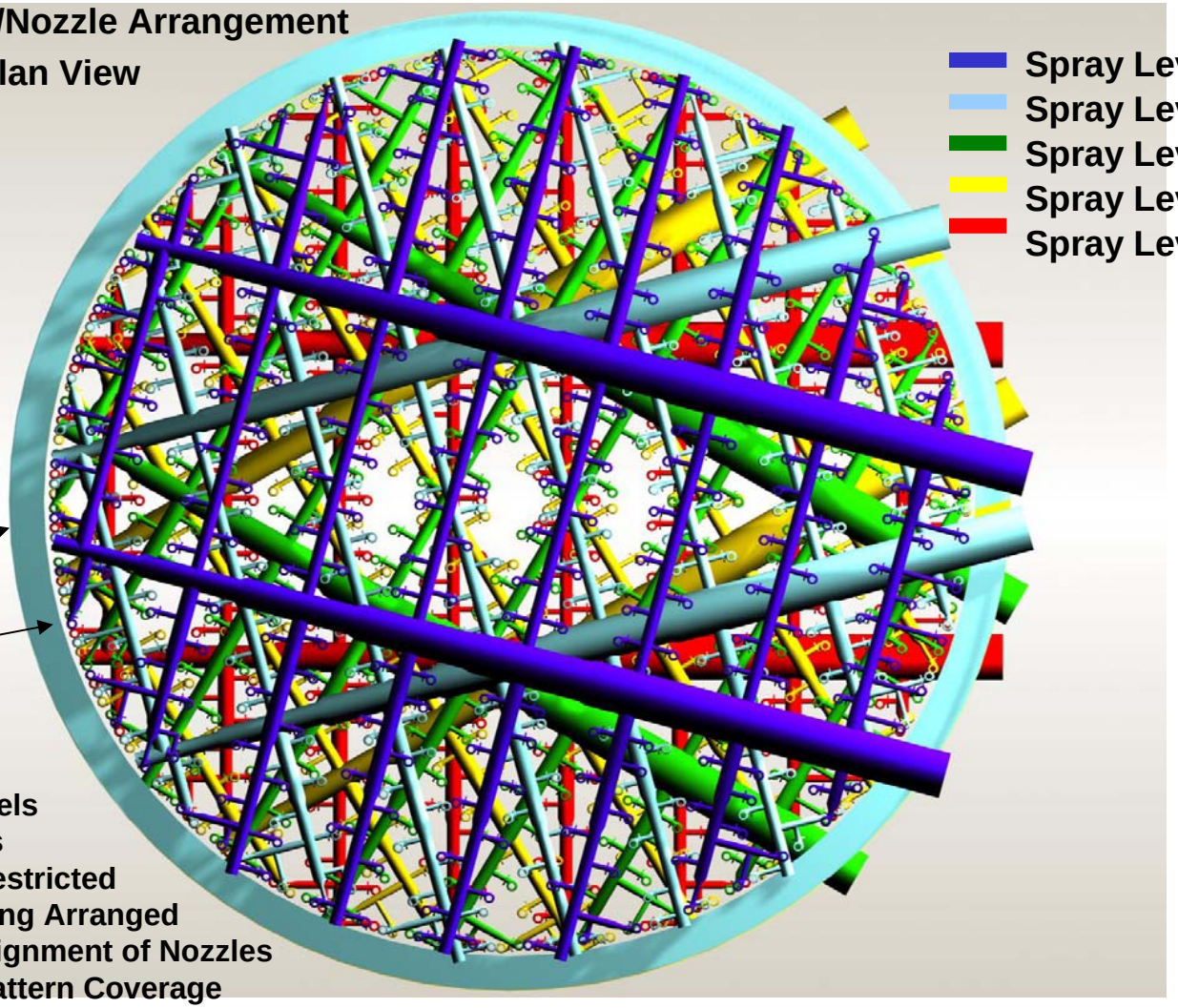




Typical Spray Header Branch Line

Spray Header/Nozzle Arrangement

Plan View

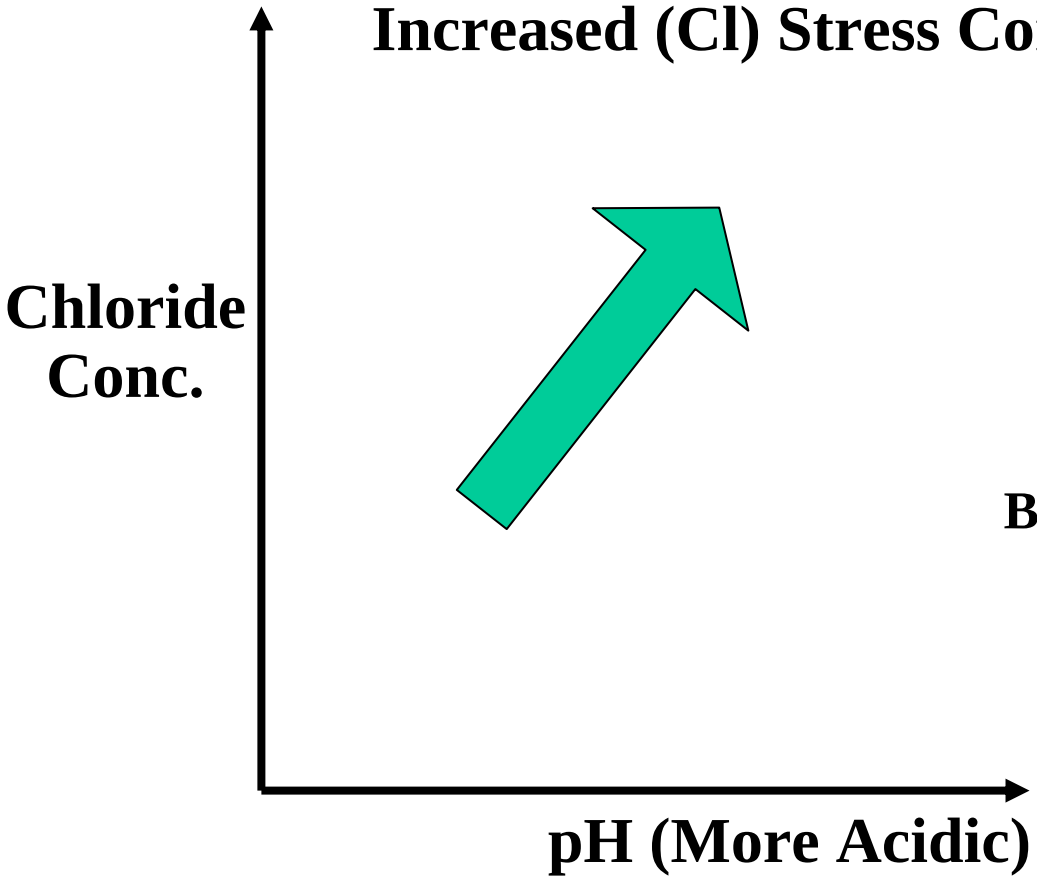


- Wall Ring @ Spray Levels 2 & 4 Ensure No Gases Flow Thru At Wall Unrestricted
- Spray Nozzles and Piping Arranged to Minimize Vertical Alignment of Nozzles and Maximize Spray Pattern Coverage

Alloy Selection Criteria

Increased Pitting & Crevice Corrosion Potential

Increased (Cl) Stress Corrosion Cracking Potential



Need

Pitting & Crevice Corrosion Resistance

SCC Resistance

Both Shop & Field Fabricate-ability

Weld-ability

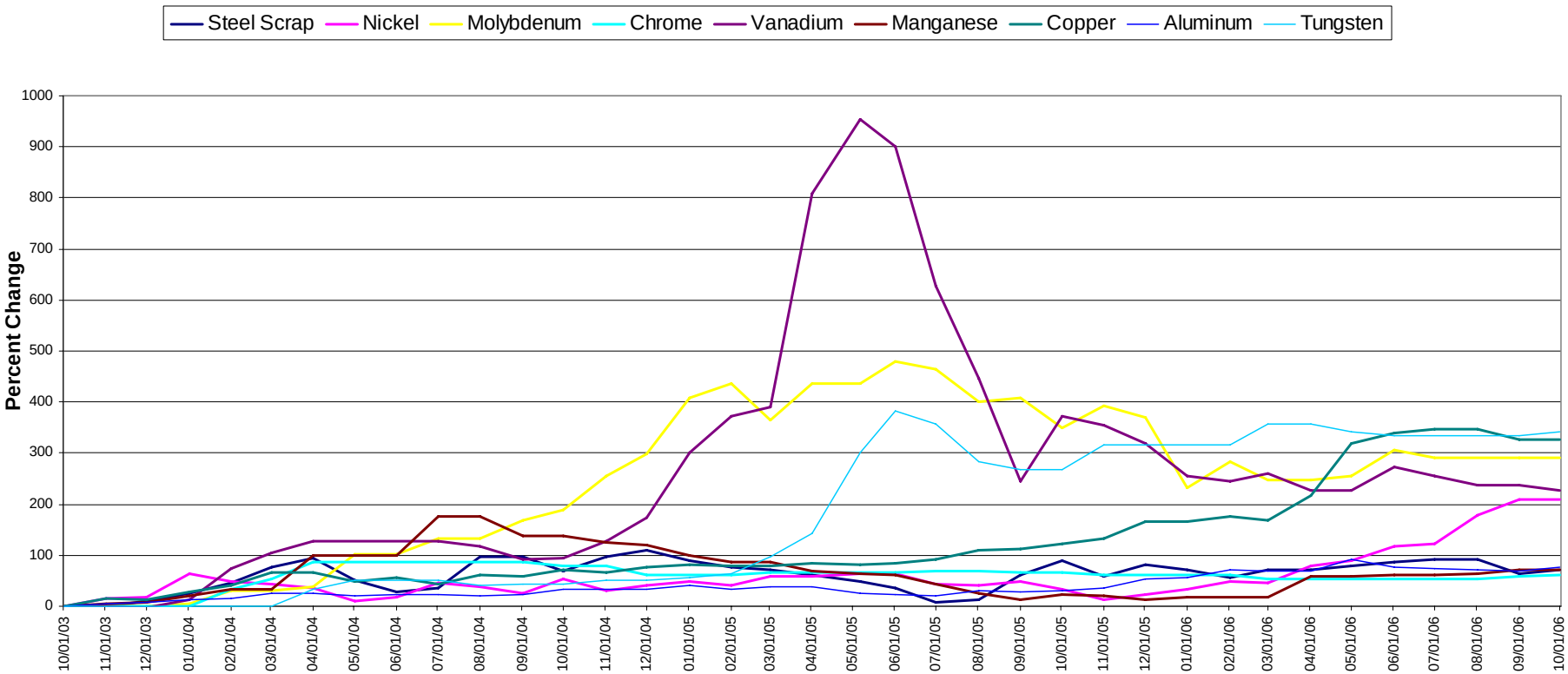
Availability

Economics

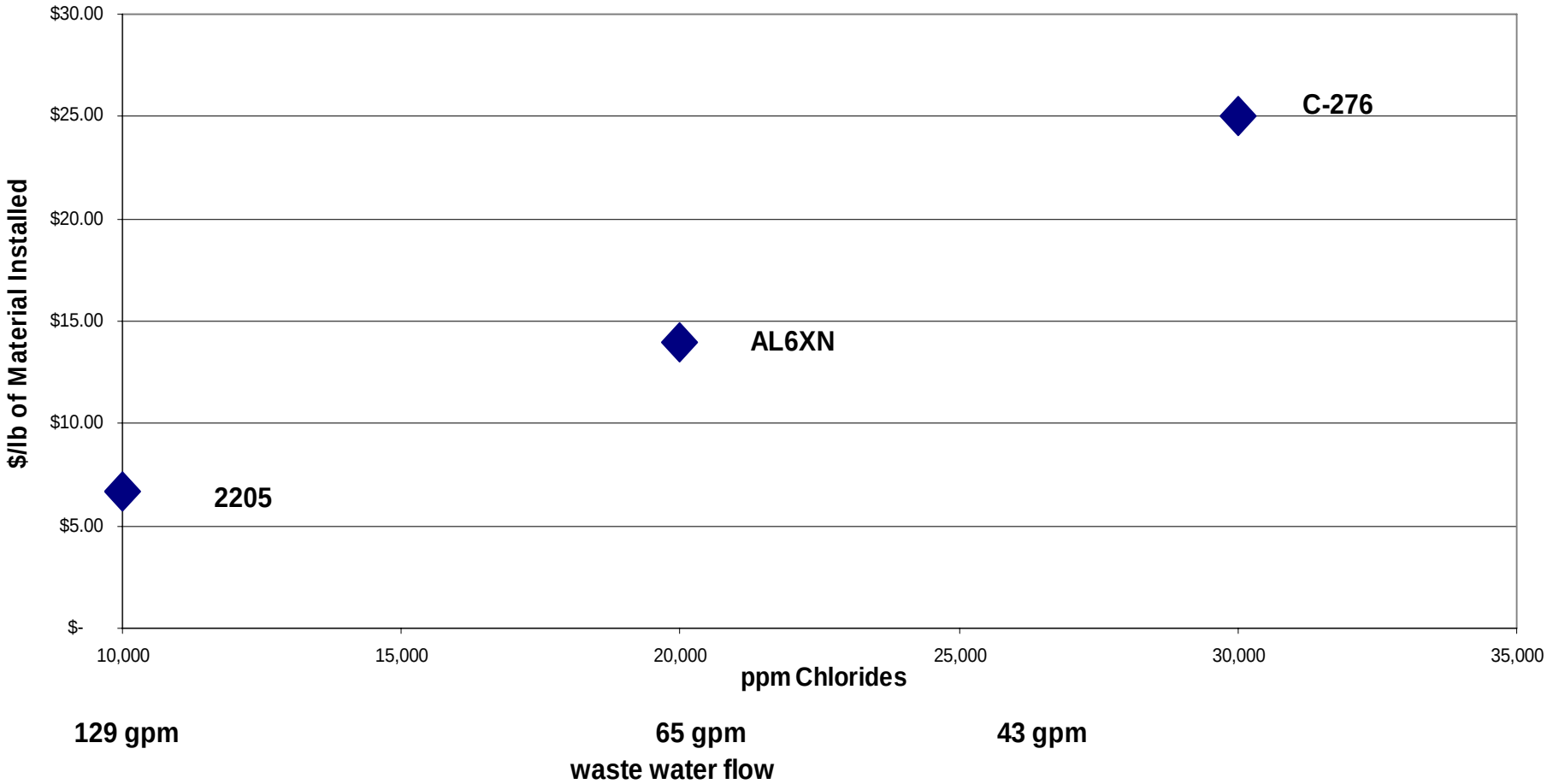
Materials of Construction	Design Chloride Limits (ppm)	GPM Wastewater
317LMN Stainless Steel (S31726)	8,000	287
Duplex 2205 Stainless Steel (S32205)	12,000	141
Super Duplex 255 Stainless Steel (S32550)	20,000	115
Super Austenitic 6% Mo Stainless Steel (N08367)	40,000	57
C-276 (N10276)	50,000	46
Carbon Steel/Glass Lined	50,000	46
Carbon Steel/Rubber Lined	50,000	46
Concrete/Tile Lined	> 50,000	46
Concrete/PP Lined	50,000	46

Materials of Construction	Installed Cost Ranking **O&M cost not included**
317LMN Stainless Steel (S31726)	1
Duplex 2205 Stainless Steel (S32205)	2
Super Duplex 255 Stainless Steel (S32550)	3
Super Austenitic 6% Mo Stainless Steel (N08367)	4
C-276 (N10276)	7
Carbon Steel/Glass Lined	1
Carbon Steel/Rubber Lined	1.5
Concrete/Tile Lined	4
Carbon Steel/Tile Lined	6
Concrete/PP Lined	3

Metal Price Trends (Source: AMM)



Cost of FGD Vessel Materials



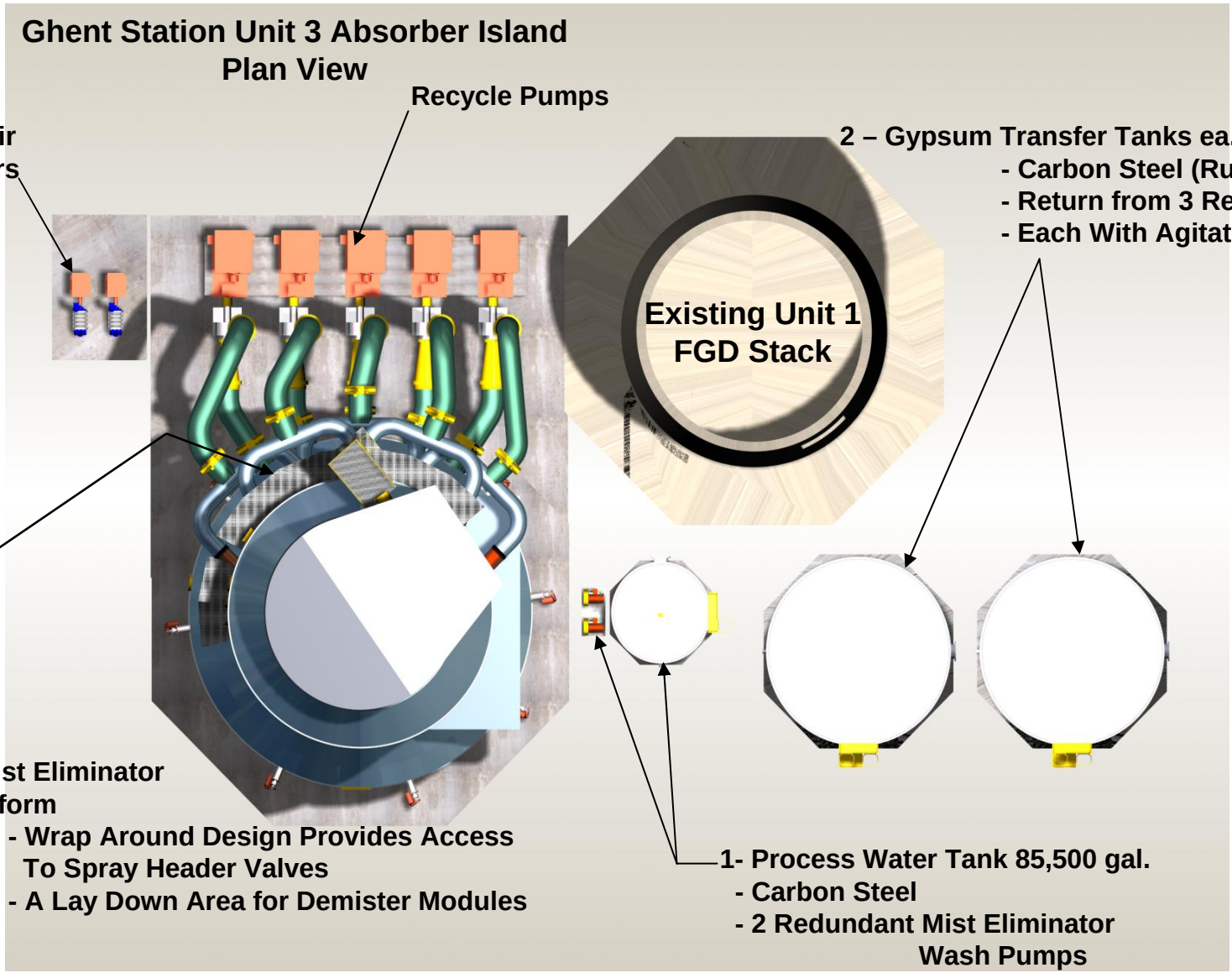
Owners Decisions

- Redundancy
  - Pumps
  - Ball Mills – 3 x 50% or 2 x 100%
  - Dewatering
  - Spares
- Organic Acids
- Waste Water
- Gypsum Markets/landfilling

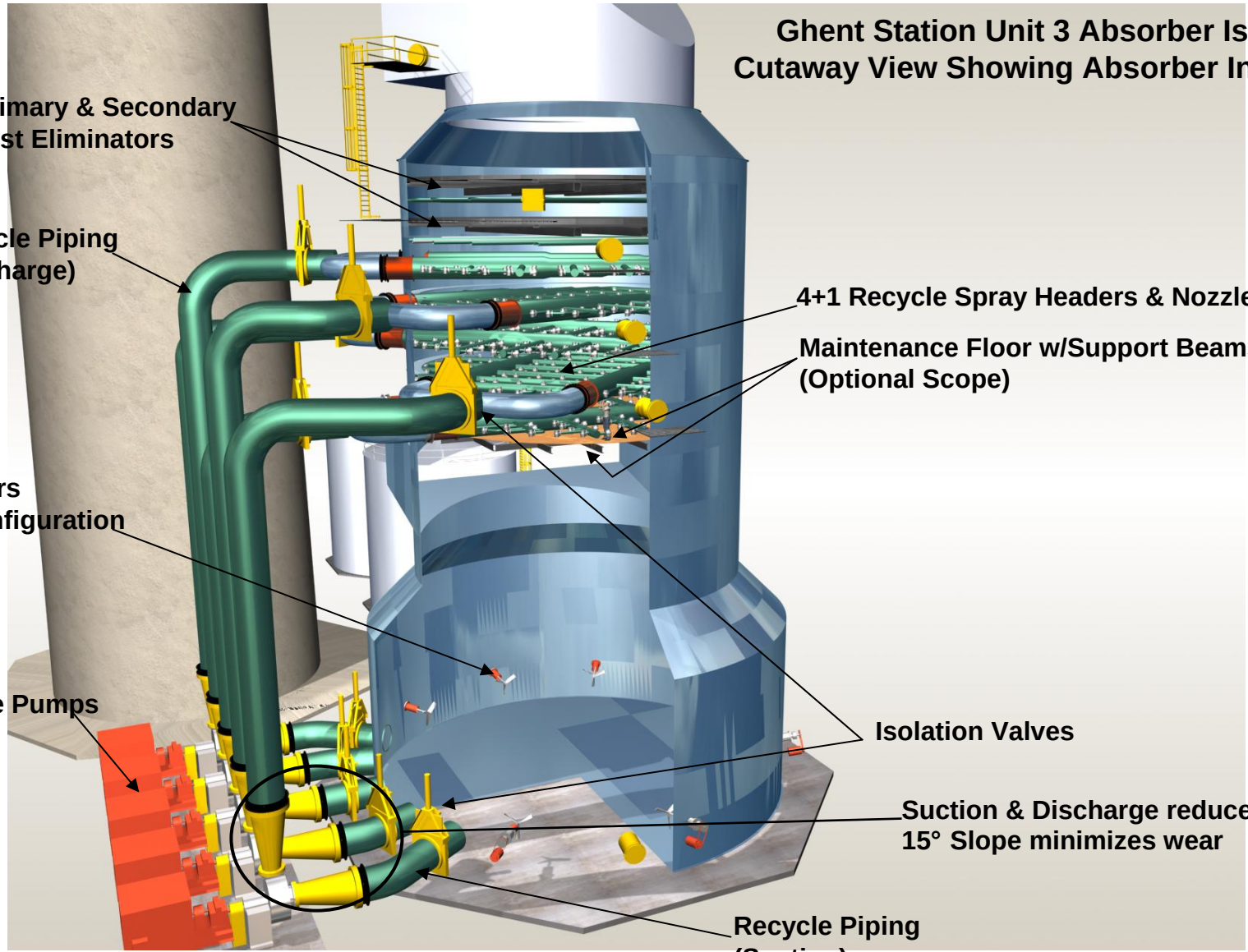
Absorber Access

- **Safety First**
  - Confined Space
  - Fall Protection
  - Personal Safety Equipment
  - Working Conditions: Lighting, GFIs, Tools, Noise, Welding. Flash Protection, etc.
- Maintenance
  - Minimize outage time
  - Simple PM programs
  - Easy access for service and cleaning

Ghent Station Unit 3 Absorber Island
Plan View



Ghent Station Unit 3 Absorber Island
Cutaway View Showing Absorber Internals



Tile Lined Concrete

Project Execution

- Market volatility
  - -Materials
- Labor
- Project time lines
- Project Management tools

Equipment Delivery

In Weeks

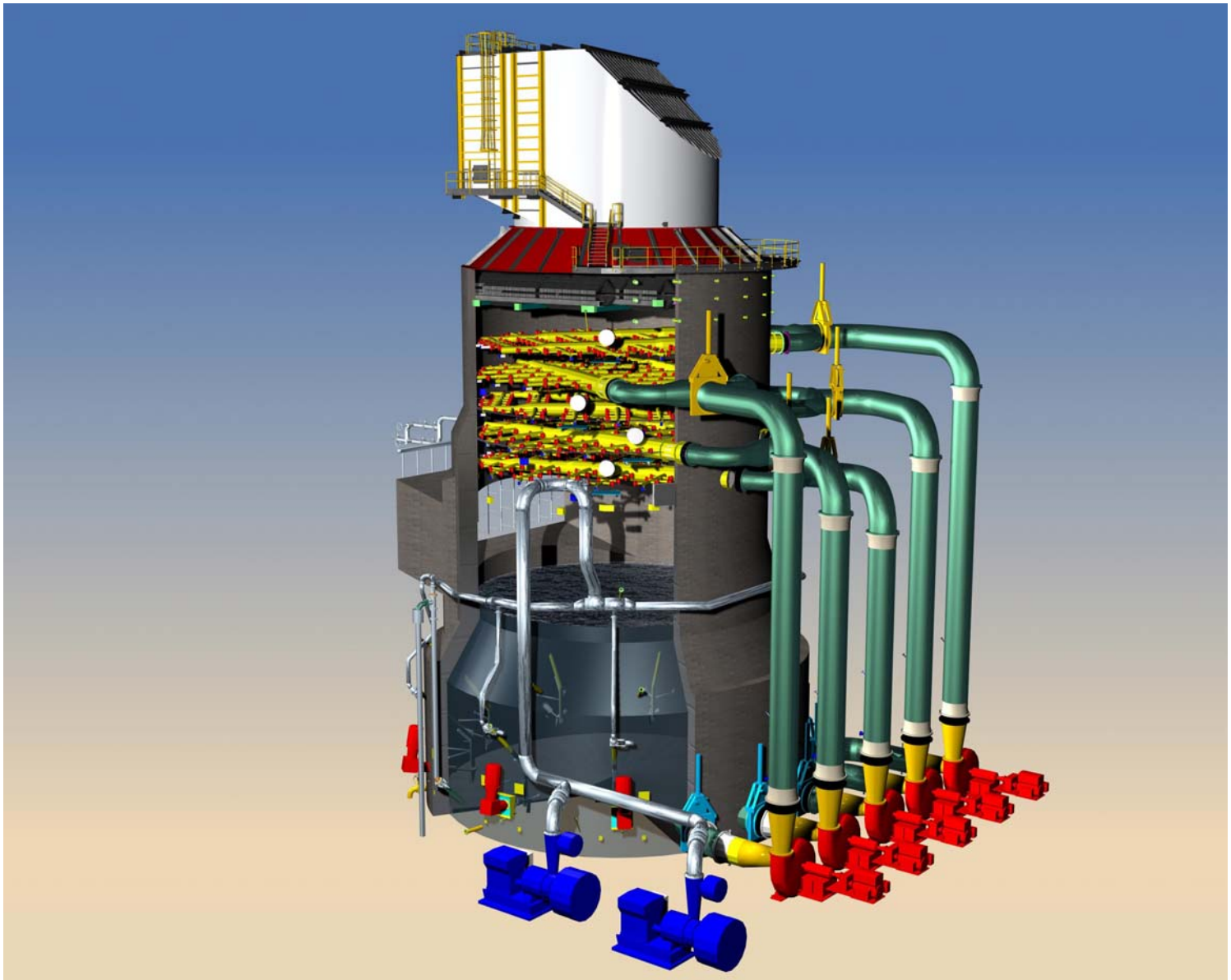
Commodity	2003	2006
Structural Shapes	8-12	20-24
Recycle Pumps	26-30	52-94
Ball Mills	26-30	64
ID Fans	72	100
SCR Catalyst	46-48	48-52

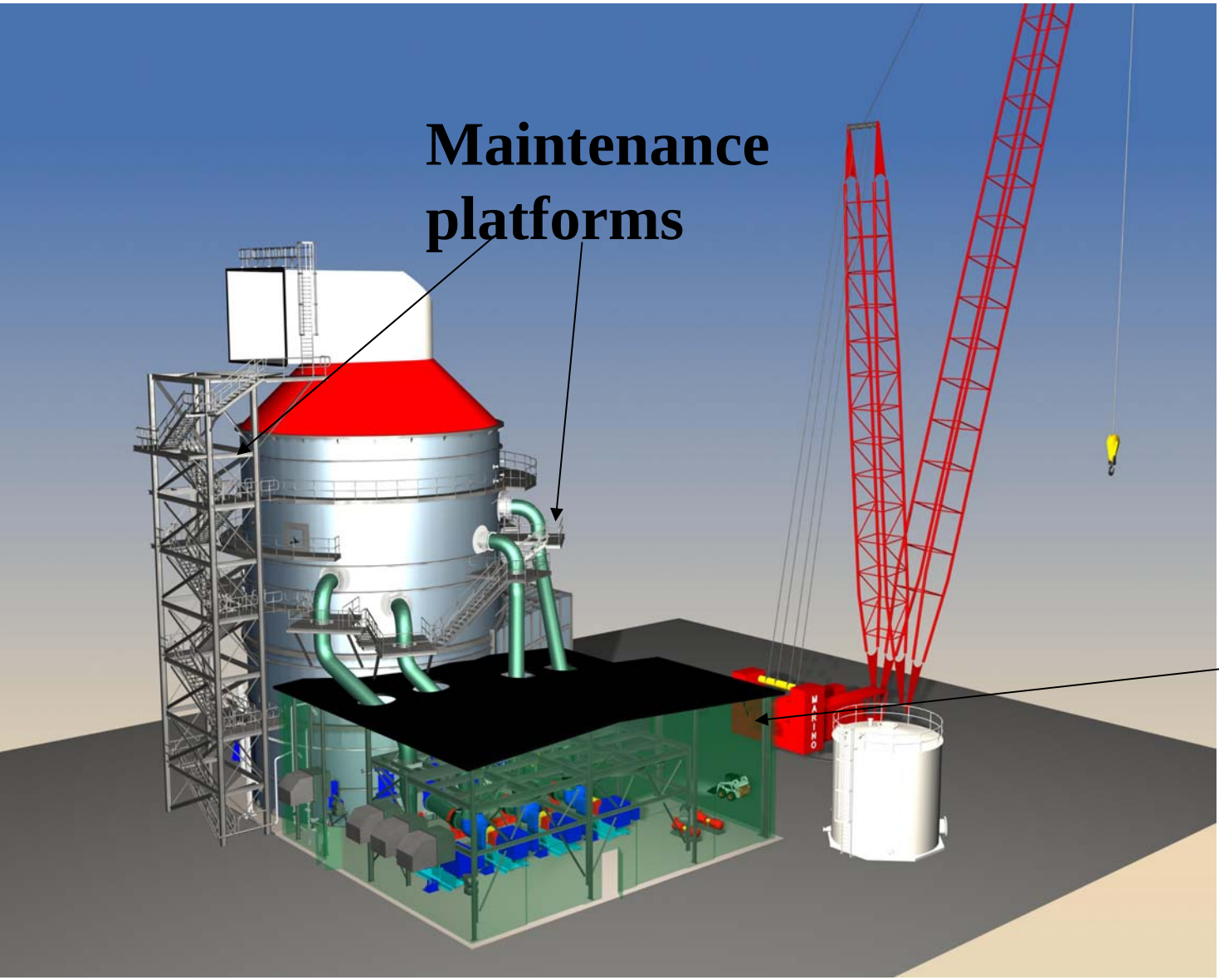
What Can be Done to Mitigate On-Site Labor Cost

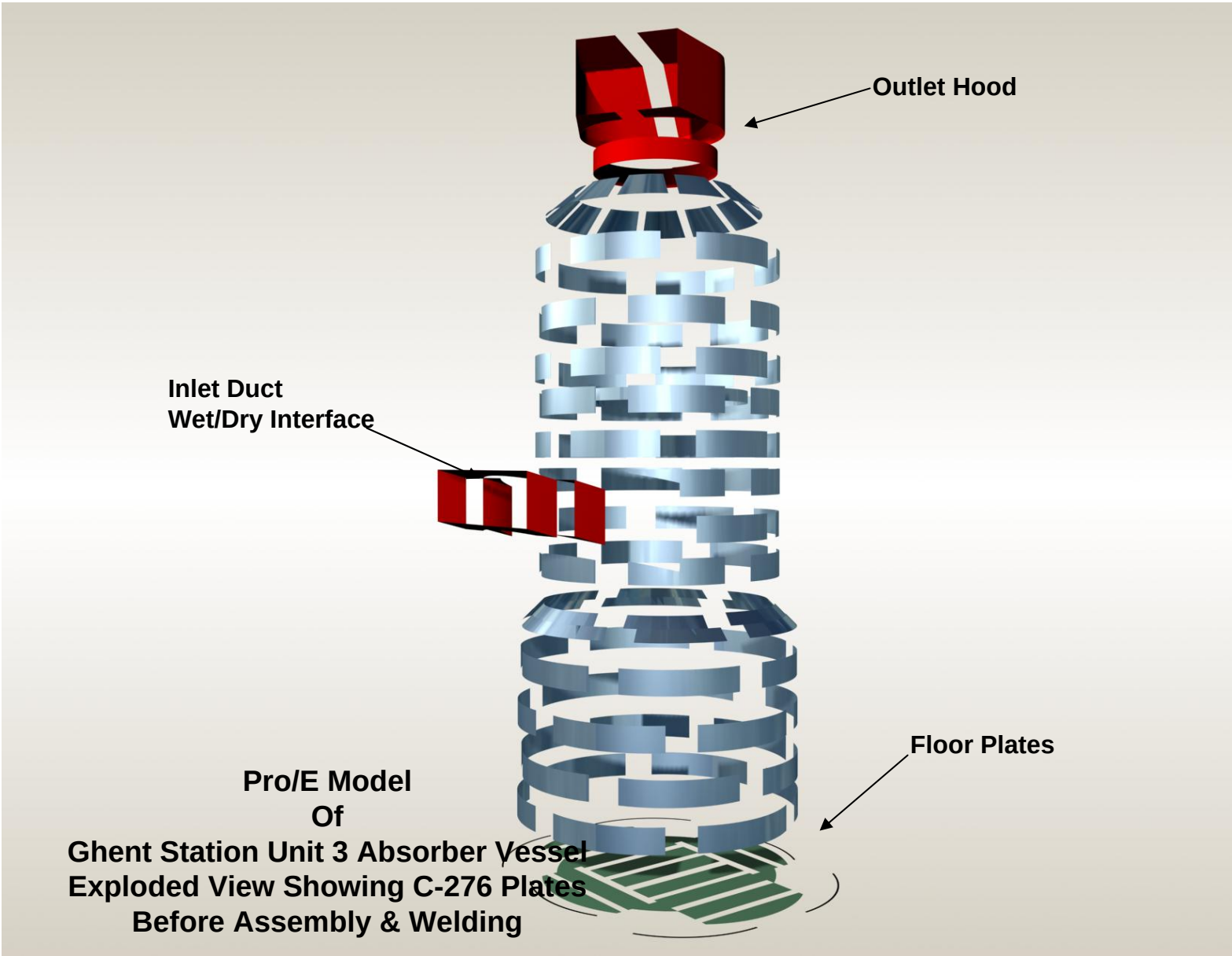
- Modularization
- Packaging components
- Alternative materials of construction
- Constructor alliances
- Standard designs
  - Rigging layouts
- Construction manuals
  - Lessons learned

What are can be done to shorten time line ?

- Qualifying new vendors
- Packaging components
- New construction techniques
- Standard designs
- New design tools





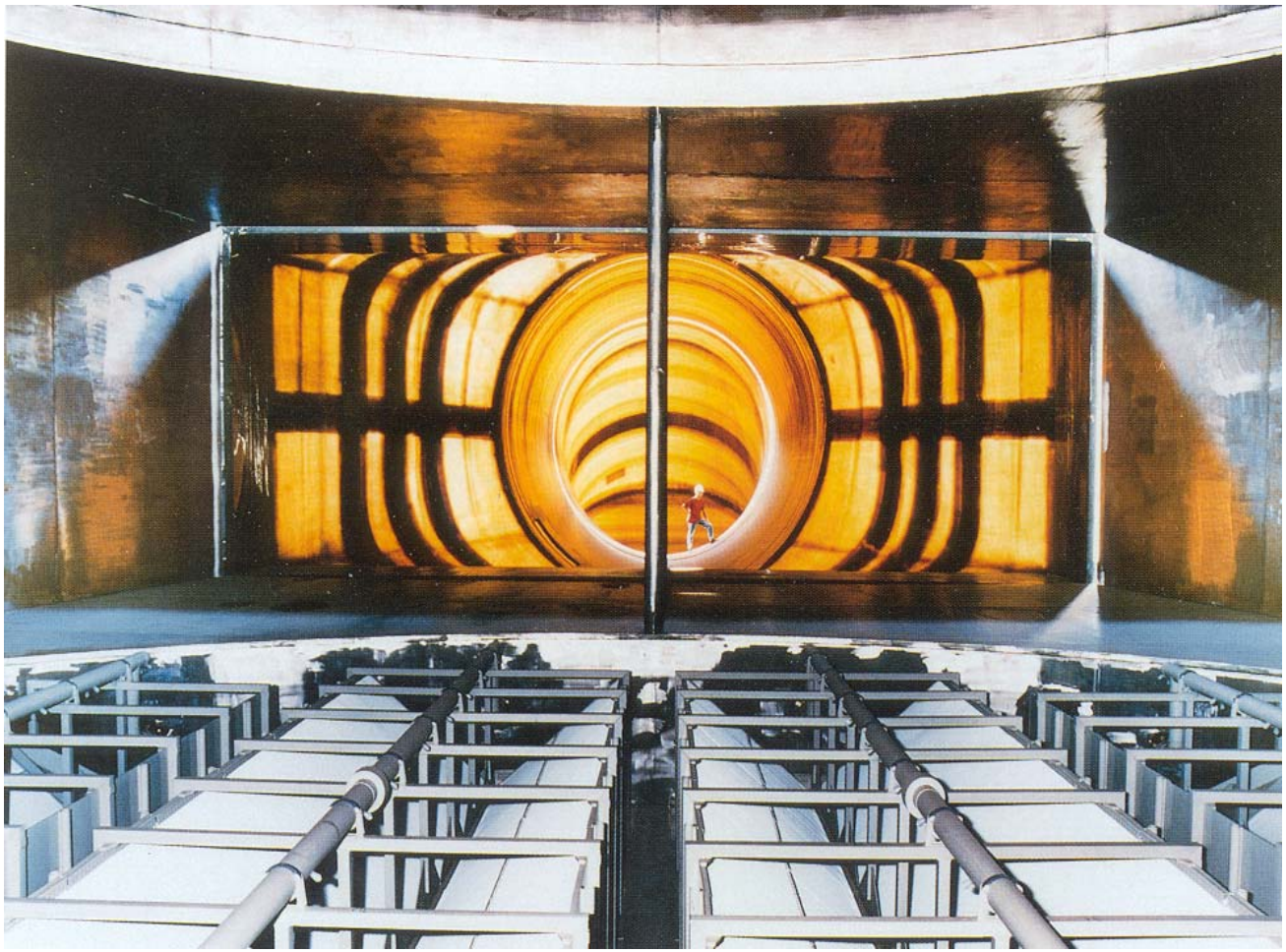


Construction

Modularization

Ohio River SCR Modules AEP Amos Tier 2

Mist Eliminator and Absorber Outlet



Introduction

- **Vectren, F.B. Culley Generating Station Units 2 & 3**
  - Two boilers feeding one WFGD System
  - WFGD supplied by BPEI (1994)
  - No Bypass

Current BPEI FGD Upgrade Projects

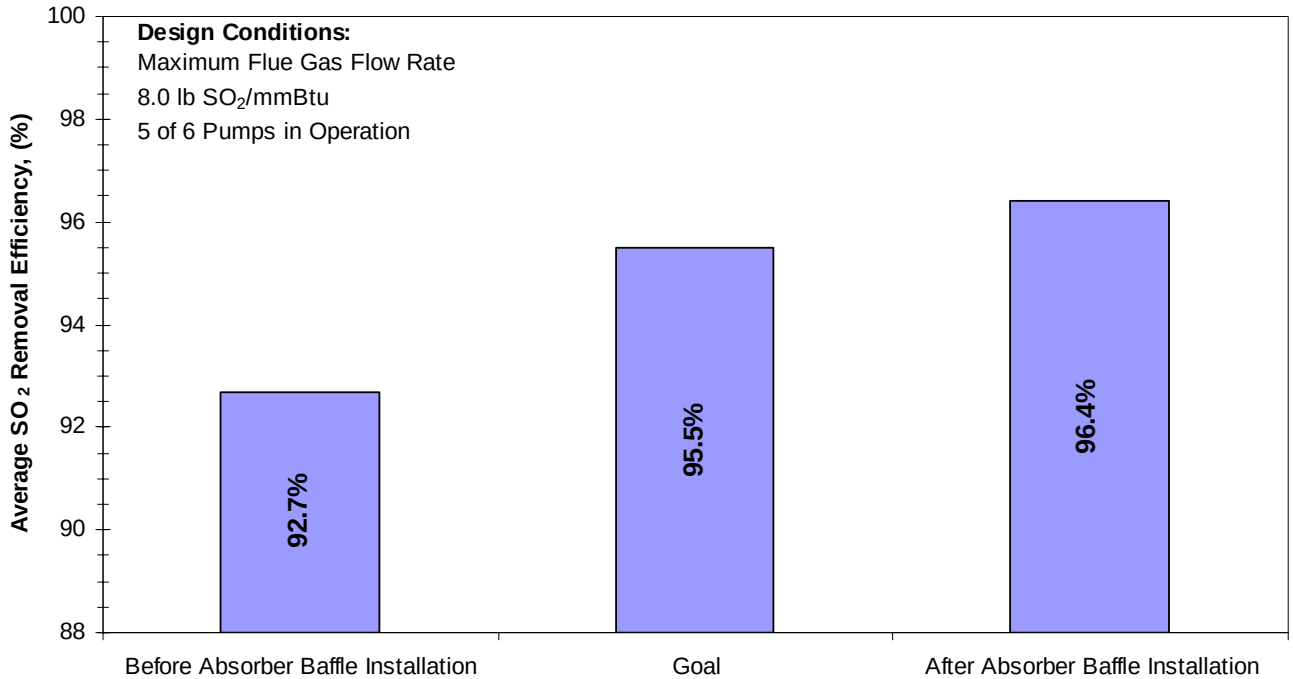
- Vectren Culley - Unit 2 & 3
  - Continuous relationship
- LG&E Trimble County – Unit 1
  - Improve operation
  - Increase removal 98%
  - Recycle pump performance

Changes in Design Parameters

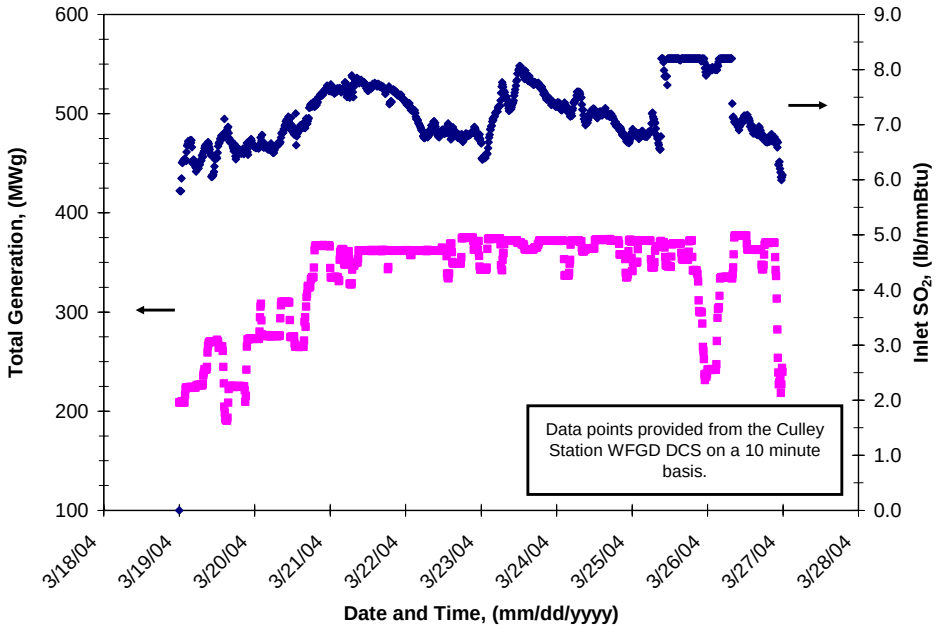
Original Design	Revised Design
368 MW	390 MW
6.5 lb SO_2/mmBtu	8.0 lb SO_2/mmBtu
95.0% SO_2 Removal Efficiency	95.5% SO_2 Removal Efficiency
Minimum of 1 Spare Recirculation Pump	Minimum of 1 Spare Recirculation Pump

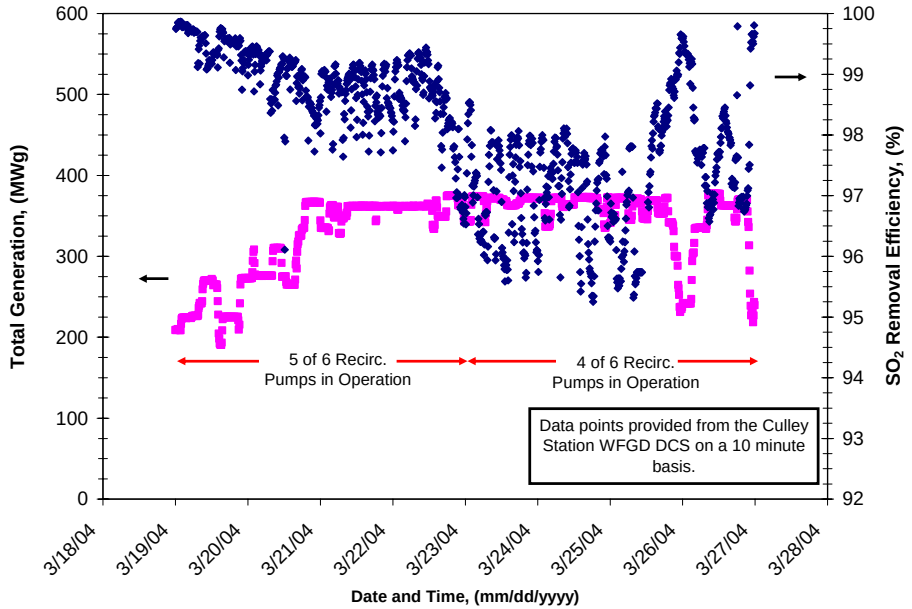
Results (Normalized Data)

Vectren, F.B. Culley Station Units 2 & 3
Absorber Performance
Average SO_2 Removal Efficiency based on
WFGD system revised design conditions



Results (Raw Data)





Accomplishments

- Exceeded performance requirements
  - Customer assured of reliable operation firing maximum sulfur coal with 5 pumps operating and 1 spare
  - Reduction in total operating cost by utilizing only 4 of 6 pumps in operation when firing typical sulfur coal
- Successfully upgraded to 2004 NSR consent decree requirements
- Achieved all goals with existing equipment

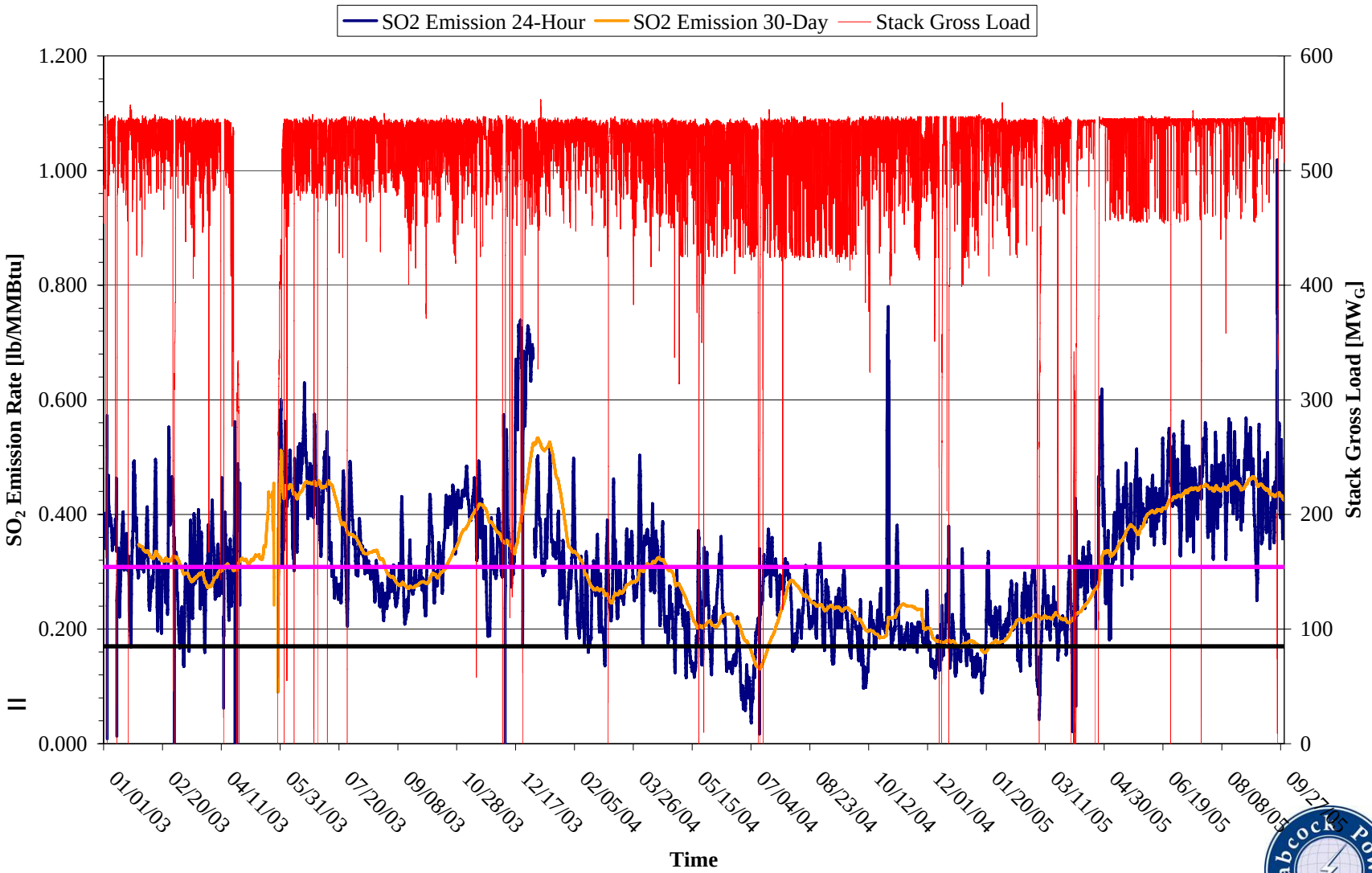
Culley Performance

WFGD Commissioned in 1994

Vectren Has Increased Boiler Load and SO_2 Loading

	Design	Actual
Boiler Load (MWe)	375	400
SO_2 Loading (lb/MMBtu)	6.5	10
SO_2 Removal Rate	95%	95%

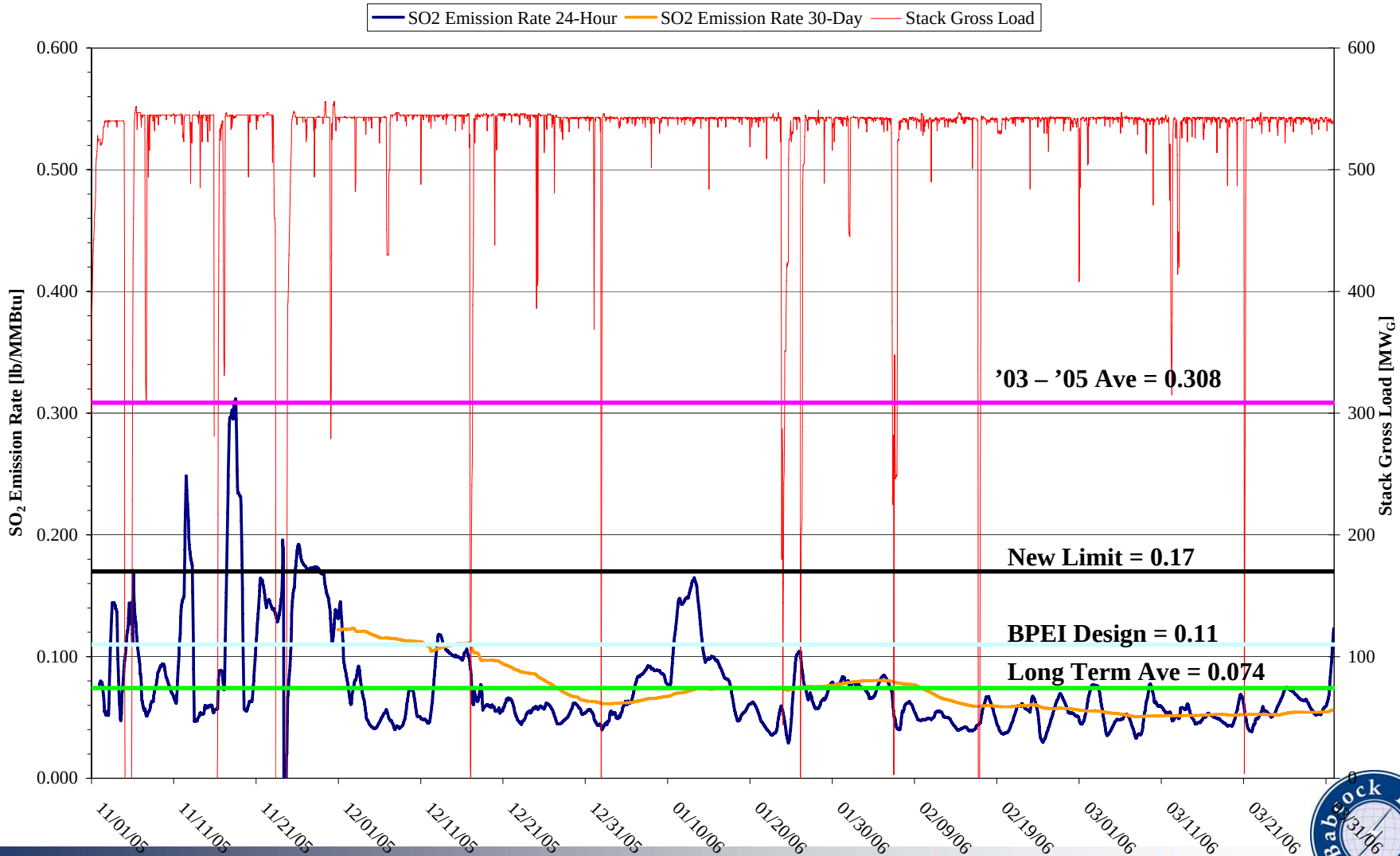
Operational History (Jan. ’03 – Sept. ’05)



Ave = 0.308

New Limit = 0.17

Upgrade Results – Long Term Performance



Thank You

Questions ??