

REINHOLD ENVIRONMENTAL Ltd.



2012 APC Round Table & Expo Presentation

July 16-17, 2012, in Baltimore, MD / Hosted by Duke Energy, Entergy,
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AQCS Technologies (Hg – HCl – PM – SO_x – NO_x) For Meeting Utility Regulations

2012 Reinhold APC Round Table
July 16, 2012




Shaw® a world of **Solutions**™

- ▶ Introductions
- ▶ Safety Minute
- ▶ Utility Air Regulations and Issues
- ▶ Flue Gas Emission Categories
- ▶ AQCS Technology Selection Process and Types
- ▶ Air Quality Control System (AQCS) Technologies - Examples
 - Overview
 - Mercury Control (Hg)
 - Acid Gases Control (HCl, HF, HBr)
 - Particulate Matter Control (TPM, PM-10, PM 2.5, SO₃/H₂SO₄)
 - Sulfur Dioxide Control (SO₂)
 - Nitrogen Oxides Control (NOx)
- ▶ Co-firing Fuels – Impacts on AQCS
- ▶ Summary
- ▶ Open Discussion



Introductions





Safety Minute





Utility Air Regulations and Issues



- Utility MATS
 - Particulate Matter
 - Hydrogen Chloride
 - Mercury

- Cross State Air Pollution Rule (CSAPR)
 - Nitrogen Oxides
 - Sulfur Dioxide

- Regional Haze (where applicable)
 - Particulate Matter
 - Sulfur Dioxide
 - Nitrogen Oxides

- Consent Decree (if applicable)
 - Particulate Matter
 - Sulfur Dioxide
 - Nitrogen Oxides
 - Other

Related Potential Future Regulatory Environment



- National Ambient Air Quality Standards (NAAQS)
- Coal Combustion Residuals (CCRs)
- GHG NSPS (potential)
- Thermal Power Plant Cooling Water Intake (316 b)
- Waste Water Discharge Issues
- Permit Renewal Process

Flue Gas Emission Categories



Flue Gas Emission Categories



- ▶ Mercury (Hg)
- ▶ Hydrogen Chloride (HCl)
- ▶ Particulate Matter (filterable and condensable)
- ▶ Opacity (%)
- ▶ Sulfur Trioxide (SO₃)/Sulfuric Acid Mist (H₂SO₄)
- ▶ Hazardous Air Pollutants (HAPs)
- ▶ Sulfur Dioxide (SO₂)
- ▶ Nitrogen Oxides (NO_x)
- ▶ Carbon Monoxide (CO)
- ▶ Volatile Organic Compounds (VOC)
- ▶ Ammonia Slip (NH₃)
- ▶ Other

- Utilities may consider a range of options in addressing the regulatory environment.
- One of several options is to evaluate different retrofit air quality control system (AQCS) technologies for flue gas cleaning.



**Selection Process for AQCS Technologies
Coal-Fired Power Plants**

Factors Considered in AQCS Technology Selection



- Stack emission requirements.
- Fuel type and flue gas properties.
- Site-specific technical and economic (capital and annual O&M costs).

Site-specific technical and economic (capital and annual O&M costs)

- Financial factors and costs (e.g. economic life, interest rate, unit costs, etc.)
- Size of plant,
- Capacity factor,
- Reagent type and usage rate,
- Byproduct type and production rate,
- Electrical power usage,
- Water type and usage rate,
- Waste water production rate and permit issues,
- Steam requirement (if required),
- Cooling water usage (if required),
- Impacts on the existing draft system, stack, plant electrical distribution and other systems,

Construction and Balance of Plant Issues



Ductwork in Staging Area



Building Foundation



Pipe and Cable Tray Back to Byproduct Silo

Site-specific technical and economic (capital and annual O&M costs) (con't)

- Impact of the retrofit AQCS on the existing air quality control (AQC) equipment at the power plant (e.g. PAC or Trona impact on flyash),
- Methods to dispose or reuse scrubber waste byproducts and/or conversion of scrubber by-products to useful materials,
- Real estate required for the retrofit AQCS equipment,
- O&M personnel (staffing),
- Maintenance required, including parts replacement (e.g. bag/cage),
- Spare part requirements,
- System reliability required,
- Compatibility of retrofit AQCS with any future potential systems such as cooling water systems, waste water systems, solid byproduct waste landfill projects, and carbon dioxide (CO₂) capture systems,
- Permit issues, including issues related to retrofit AQCS and byproducts

Maintenance Issues - example



Replacement of PJFF Old Cages



New PJFF Cags



New PJFF Bag (fit demonstration)

Field Demonstration Projects – technology selection HCl, Hg, PM, SO₂, and SO₃ (examples)



Field Demonstration	Examples - Summary Project Descriptions
1	DSI demonstration testing program for HCl, Hg, SO ₂ , and SO ₃ reduction with milled Trona, milled SBC, coal mercury oxidation additives, and powdered activated carbon injection process on a coal-fired power plant to determine capability to meet the proposed MATS emissions limits.
2	DSI field demonstration test program at coal-fired power plants for dry sorbent injection in front of the existing electrostatic precipitators (ESP)s to determine the removal of acid gases (HCl and SO ₂) and the impact on the operation of the ESPs and fly ash handling system.
3	DSI Field Testing trials for eight units plus PAC for eight sites – SO ₂ /HCl/Hg/PM control.
4	DSI Field Testing trials for one unit – HCl control
5	DSI Field Testing for one unit and PAC for one unit – SO ₂ /PM/Hg control
6	DSI Field Testing for one unit – SO ₂ /HCl/Hg/PM control
7	PAC Field Testing for three units – Hg control
8	PAC Field Testing for one unit – Hg control
9	PAC Field Testing for one unit – Hg control
10	Field Testing for one unit – Hg control
11	PAC/Trona Field Testing for two units –HCl/SO ₃ /Hg control
12	DSI Field Testing for one unit – SO ₃ control
13	DSI Field Testing for one unit – SO ₃ control

Typical Field Testing Instrumentation



Flue Gas Pressure Drop (Manometers)

**Types of AQCS Technologies
Coal-Fired Power Plants**



Mercury (Hg)

AQCS Technologies Options



- ▶ Fuel type (coal type, oil, biomass fuels, coke, and other fuels)
- ▶ Use existing/upgrade FGD System (co-benefit Hg rem., Hg re-emission additive)
- ▶ Coal mercury oxidation additives (e.g. PRB coal)
- ▶ Use existing SCR oxidation (co-benefit neutral Hg → ionic Hg, e.g. PRB coal)
- ▶ Activated Carbon Injection (ACI) (brominated, non-brominated PAC, etc.)
- ▶ Flue gas mercury oxidation additives
- ▶ Mercury Re-emission additive with FGD System
- ▶ Use existing/upgraded Electrostatic Precipitators (ESP)
- ▶ Use existing/upgraded Fabric Filter (PJFF)
- ▶ Multi-pollutant AQCS (e.g., ReACT for SO₂/NO_x/Hg/PM removal , CCS, co-benefit rem. of Hg)
- ▶ Co-firing Coal with natural gas
- ▶ Other

Hydrogen Chloride (HCl), Sulfur Dioxide (SO₂), and HAPs AQCS Technologies



- ▶ Fuel type (coal type, oil, biomass fuels, coke, and other fuels)
- ▶ Use existing FGD System (co-beneficial removal)
- ▶ Upgrade existing FGD System
- ▶ Dry Sorbent Injection (DSI) with PJFF or ESP
- ▶ Spray Dryer Absorber (SDA) with PJFF or ESP
- ▶ Circulating Dry Scrubber (CDS/NID) with PJFF or ESP
- ▶ Wet FGD (LSFO)
- ▶ Multi-pollutant AQCS process (ReACT for SO₂, with co-benefit rem. of NO_x/Hg/PM)
- ▶ Co-firing Coal with natural gas
- ▶ Other (potential future CO₂ capture, combined SO₂/CO₂ capture along with other flue gas species)

Particulate Matter and Opacity Control AQCS Technologies



- ▶ Use existing/upgrade ESP System
- ▶ Use existing/upgrade PJFF System
- ▶ Retrofit ESP System
- ▶ Retrofit PJFF System
- ▶ Convert ESP to PJFF System
- ▶ DSI/SDA/CDS/NID/LSFO in combination with ESP or PJFF (filterable plus condensable) (co-benefit removal $\text{SO}_2/\text{SO}_3/\text{H}_2\text{SO}_4/\text{HCl}/\text{HAPs}/\text{etc.}$)
- ▶ Multi-pollutant AQCS (e.g., ReACT for $\text{SO}_2/\text{NO}_x/\text{Hg}/\text{PM}$ removal, co-benefit removal of PM)
- ▶ Wet ESP (PM/HAPs/ $\text{SO}_3/\text{H}_2\text{SO}_4/\text{etc.}$)
- ▶ Other

Sulfur Trioxide/Sulfuric Acid Mist

AQCS Technologies



- ▶ Fuel type (PRB, vs. higher sulfur fuels)
- ▶ DSI/SDA/CDS/NID in combination with ESP or PJFF
(filterable plus condensable) (co-benefit removal $\text{SO}_2/\text{SO}_3/\text{H}_2\text{SO}_4/\text{HCl}/\text{HAPs}/\text{etc.}$)
- ▶ LSFO FGD System (co-benefit rem $\text{SO}_2/\text{SO}_3/\text{H}_2\text{SO}_4/\text{HCl}/\text{HAPs}/\text{etc.}$)(design for $\text{SO}_3/\text{H}_2\text{SO}_4$ rem)
- ▶ SCR System (SCR catalyst designed for minimal SO_2 oxidation)
- ▶ Wet ESP (PM/HAPs/ $\text{SO}_3/\text{H}_2\text{SO}_4/\text{etc.}$)
- ▶ Other

Nitrogen Oxides (NO_x) AQCS Technologies



- ▶ Fuel Combustion Optimization (LNB, etc.)
- ▶ Selective Catalytic Reduction (SCR designed to minimize NH₃ slip)
- ▶ Selective Non-Catalytic Reduction (SNCR designed to minimize NH₃ slip)
- ▶ Multi-pollutant AQCS (e.g., ReACT for NO_x reduction, with co-benefit rem. of SO₂/PM/Hg)
- ▶ Co-firing Coal with natural gas
- ▶ Other

Carbon Monoxide (CO) and Volatile Organic Compound (VOC) AQCS Technologies



- ▶ Fuel Combustion Optimization (minimize/optimize CO/VOC/NO_x)



**Examples of AQCS Technologies
Coal-Fired Power Plants**

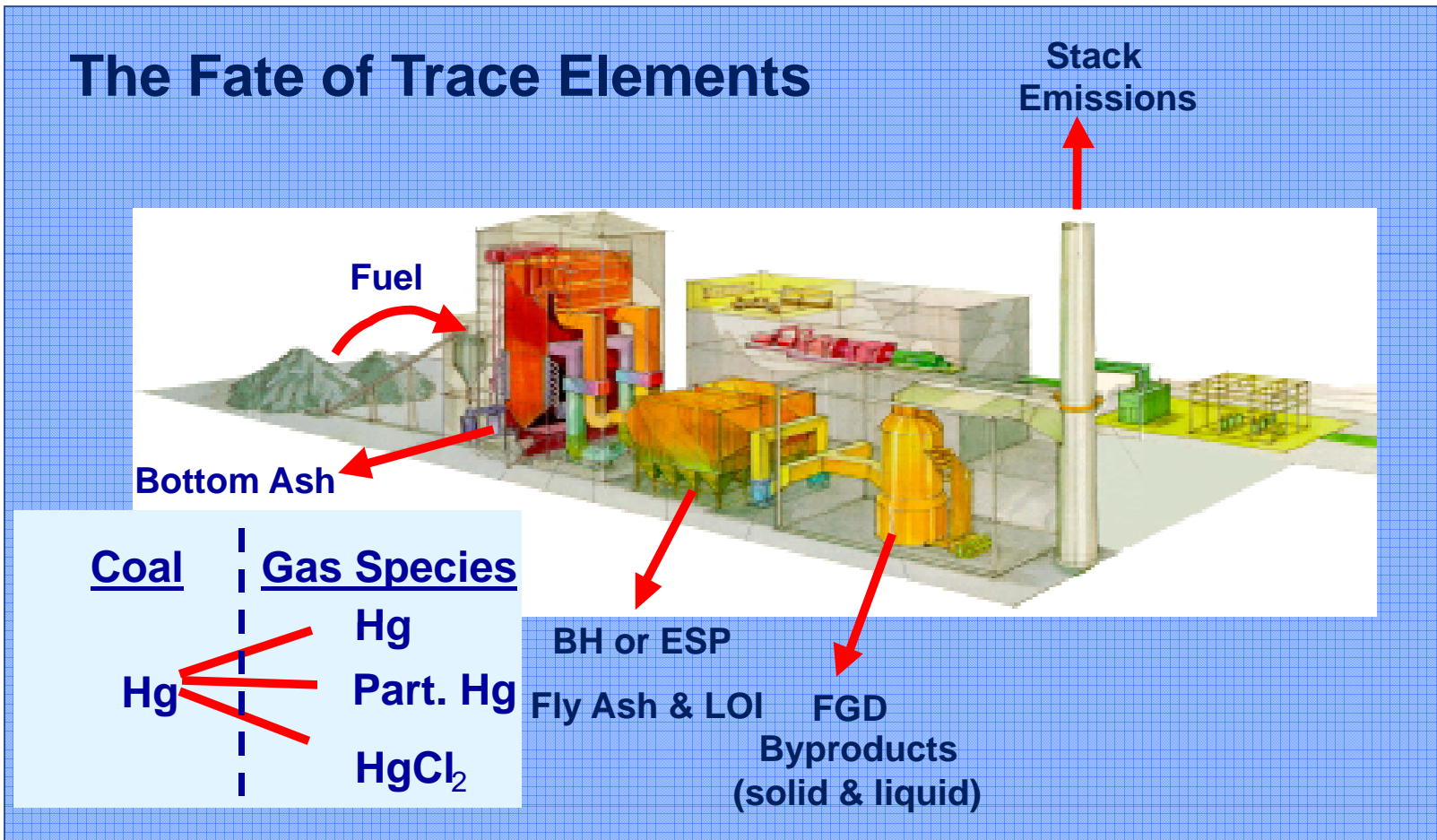




Mercury Control (Hg)



The Fate of Trace Elements



- ▶ The removal of mercury from flue gas in an air quality control device that was primarily designed to control emissions of another specie (SO₂, PM, NO_x, SO₃, CO₂, etc).
- ▶ Although this co-benefit mercury removal may be incidental, there are design and/or operational parameters to enhance Hg removal.

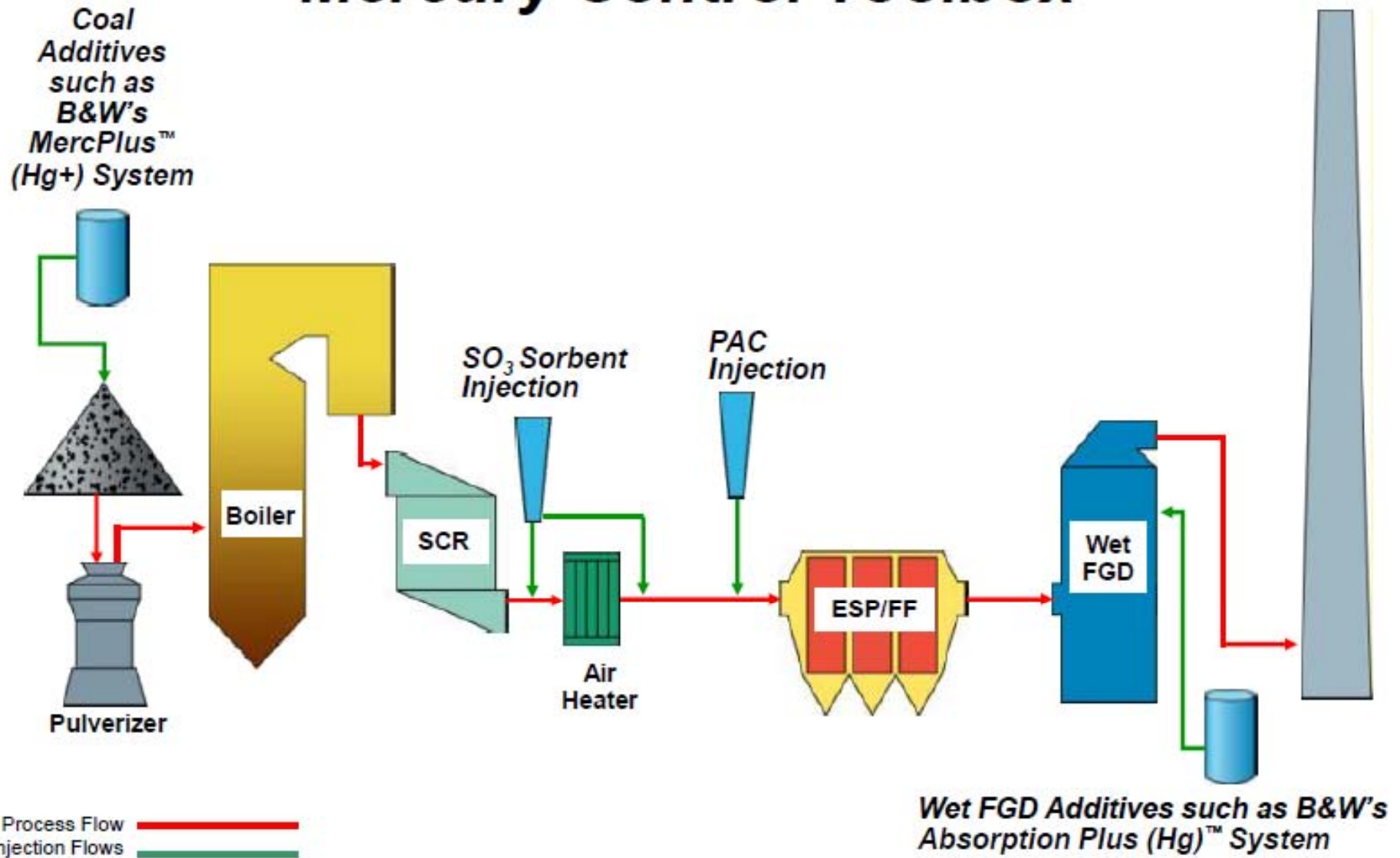
Co-benefit Mercury Removal

(degree of Co-benefit Hg reduction depends on the AQCS device, design, and process parameters)



- ▶ SCR Oxidation
 - (neutral Hg → ionic Hg)
- ▶ Existing ESP or Baghouse
 - (removes Hg-part, ash LOI for Hg+2 & Hg+0)
- ▶ CDS or SDA FGD
 - (Hg removal by lime solids adsorption, cool temp, removal of PM & solids in BH)
- ▶ Wet FGD
 - (ionic Hg & PM removal in slurry, cool temp, re-emission inhibitor additives)
- ▶ Multi-pollutant Processes
 - (ReACT, ionizer reactors, Hg oxidation, wet absorber with cool temp, WESP)

Mercury Control Toolbox



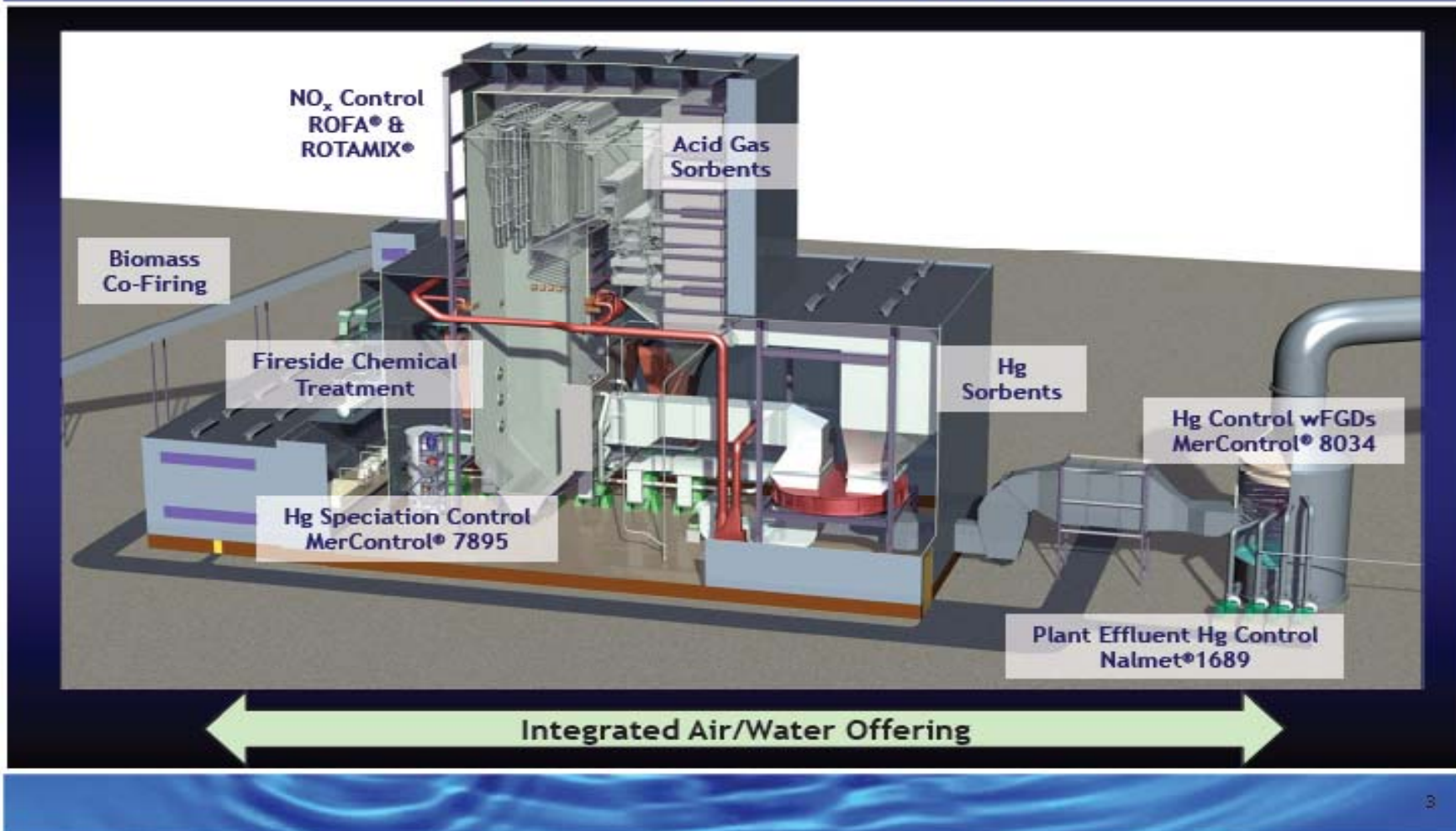
MercPlus™ Fuel Additive from B&W for Low Halogen Coals



- **Increases oxidation of elemental mercury**
- **Reduces PAC consumption**
- **May allow use of standard PAC versus more costly brominated PAC**
- **Injected onto coal prior to coal feeders**
- **Co-benefits Hg removal with FGD**



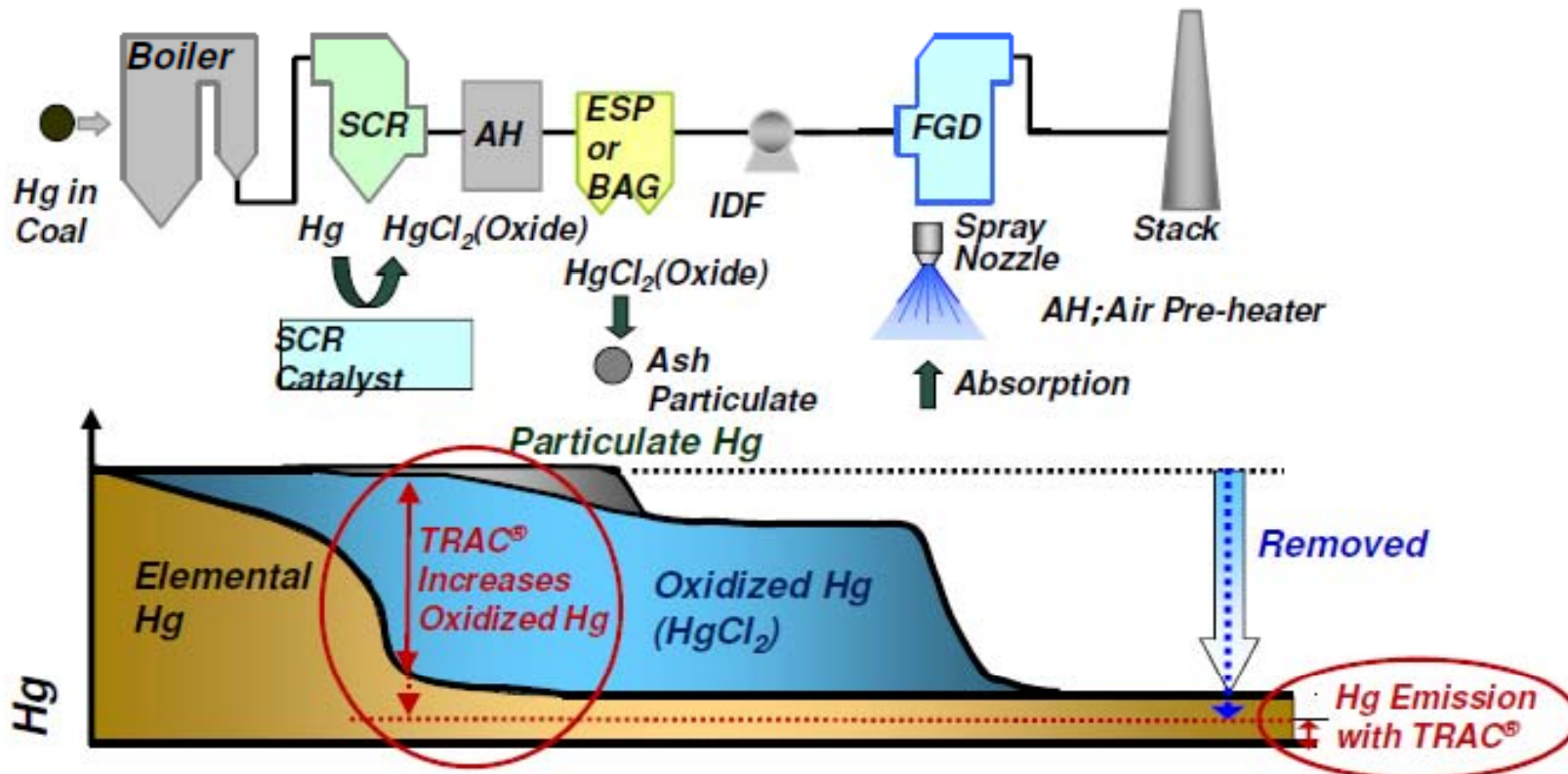
“Small Environmental Footprint” Coal-Fired Power Plant



KNX™ for Hg Removal

- KNX™ is a fuel additive that reliably and predictably provides a high degree of Mercury oxidation
- Oxidized Mercury is then more easily controlled by most types of standard air pollution control equipment

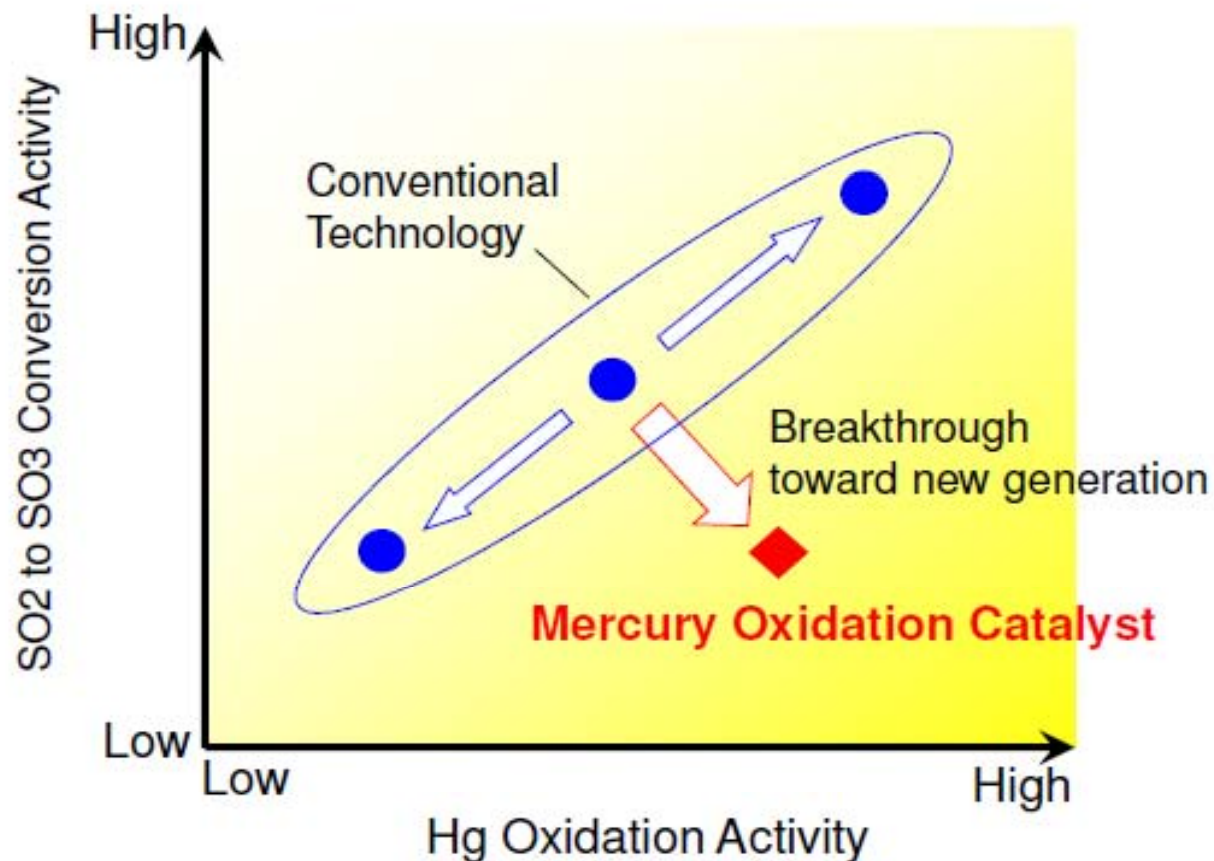
Process of Hg Removal by SCR + FGD



SCR Catalyst is a key component for mercury oxidation

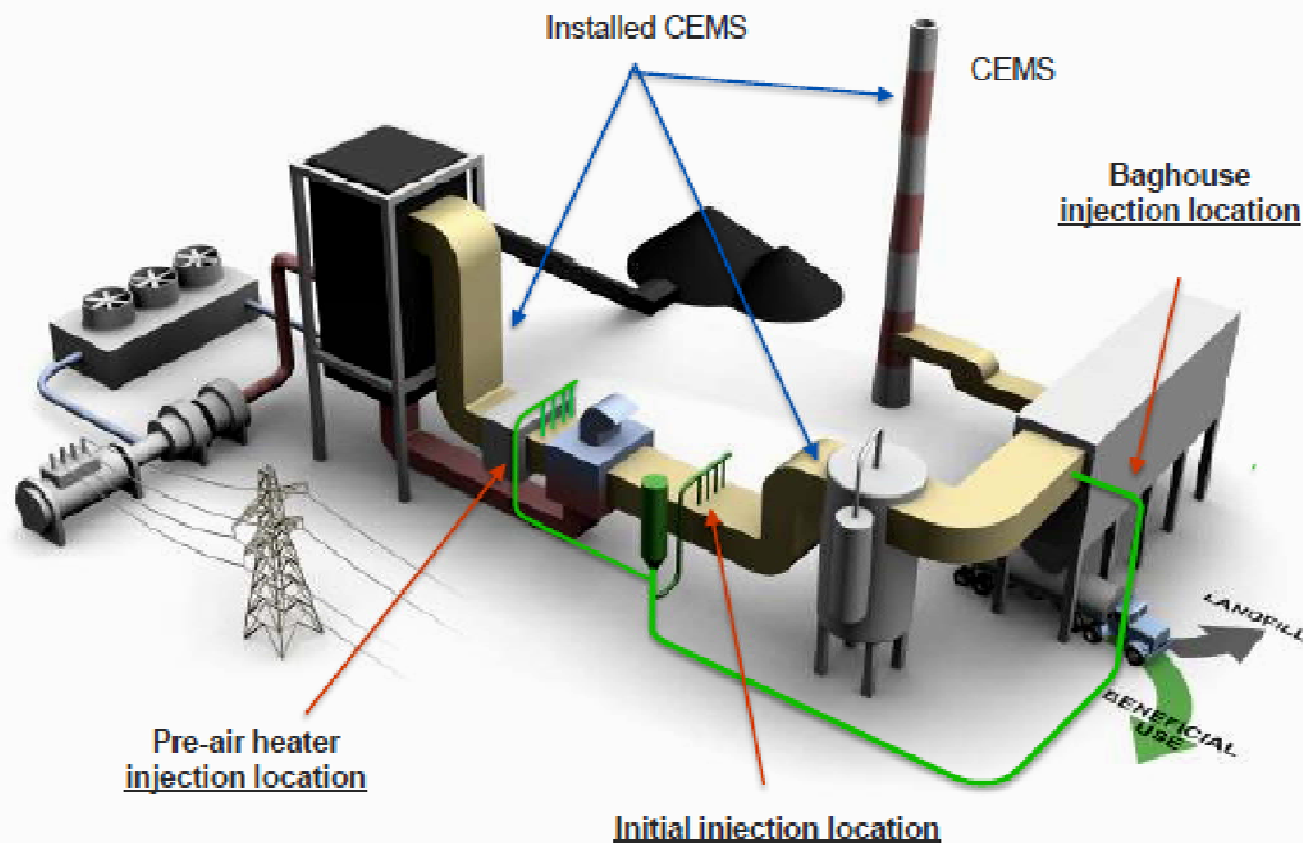
Mercury Oxidation Catalyst

Lower SO₂ conversion is required while keeping higher Hg oxidation.



Typical Injection Points (SCR / SDA / BH)

Standard ACI system utilized



Modular Construction Activated Carbon Silo



Activated Carbon Injection Installation



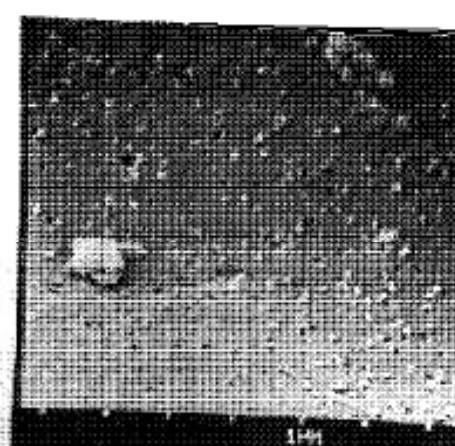
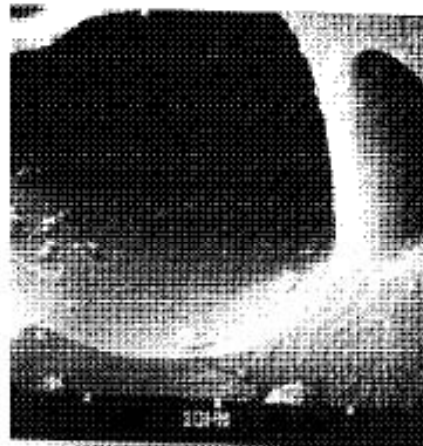
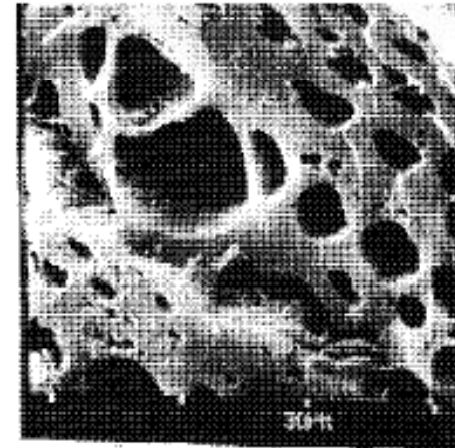
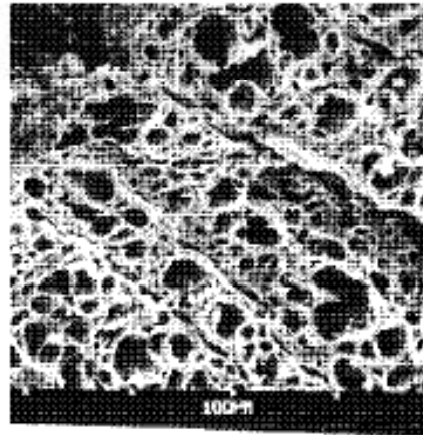
Overview - DARCO Hg-LH EXTRA

Created for use in challenging applications in the flue gas market

Produced using Norit's new patent-pending process.

Improved oxidative capability resulting in faster adsorption kinetics

Superior working capacity in bag house applications and higher efficiency in ESPs.



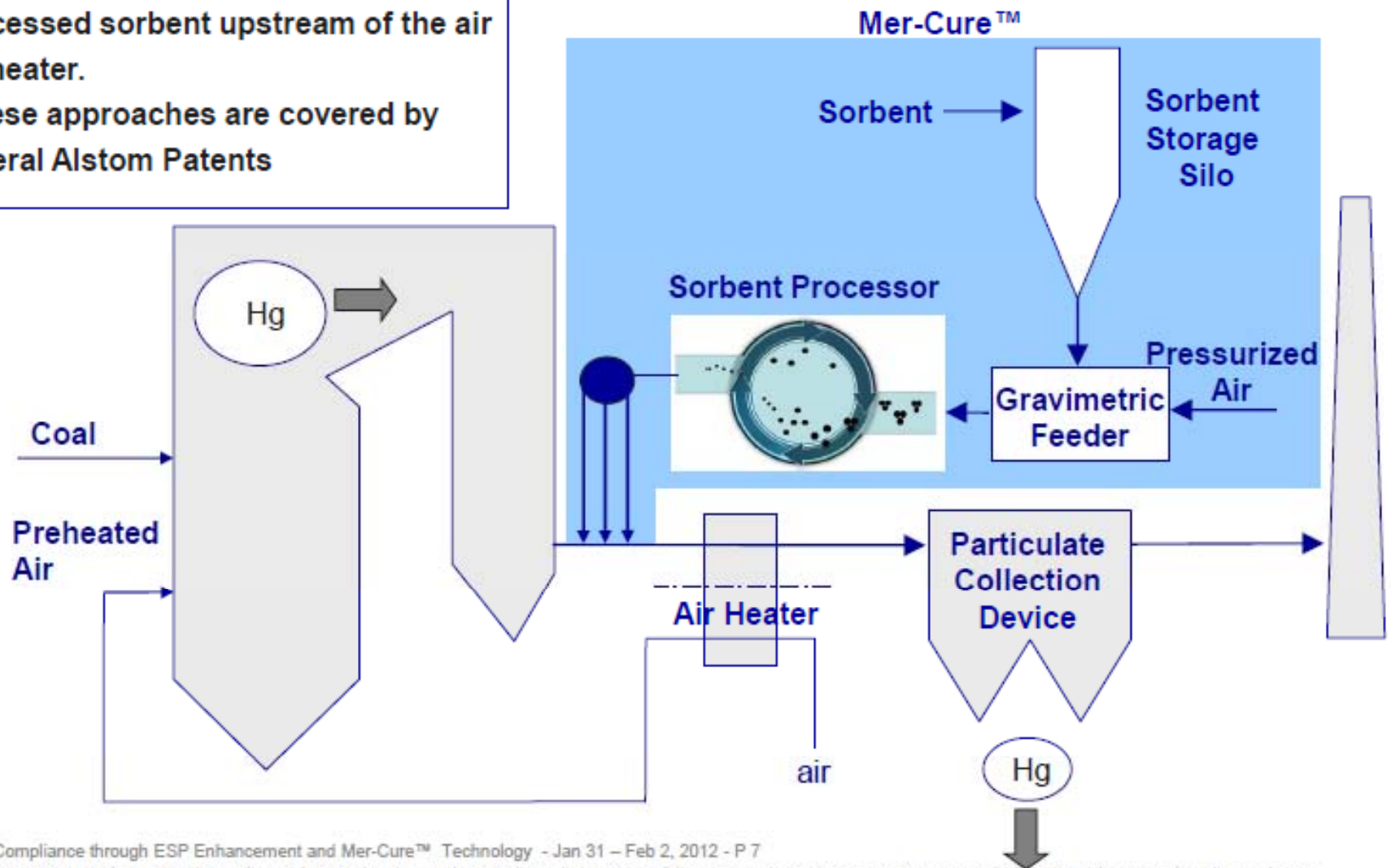
Novinda's AS-022 - Hg Removal Product

- **Non Carbon** – Mineral Based Product
 - Manufactured using a natural mineral substrate: bentonite.
 - Preserves 'beneficial use' of fly ash as a replacement for Portland cement and maintains gypsum quality.
 - Non-flammable.
 - No degradation on balance of plant.
- **Amended Silicates** - Only Commercially Available Non-Carbon Reagent for Hg control
 - Bentonite is infused with a metal sulfide.
 - Metal sulfide reacts with the mercury to form mercuric sulfide on the surface of the particle.
 - AS-022 creates a chemical reaction vs. adsorption.
 - The product is then removed from the flue gas, along with fly ash, in conventional particulate control equipment, such as a bag-house or electrostatic precipitator.

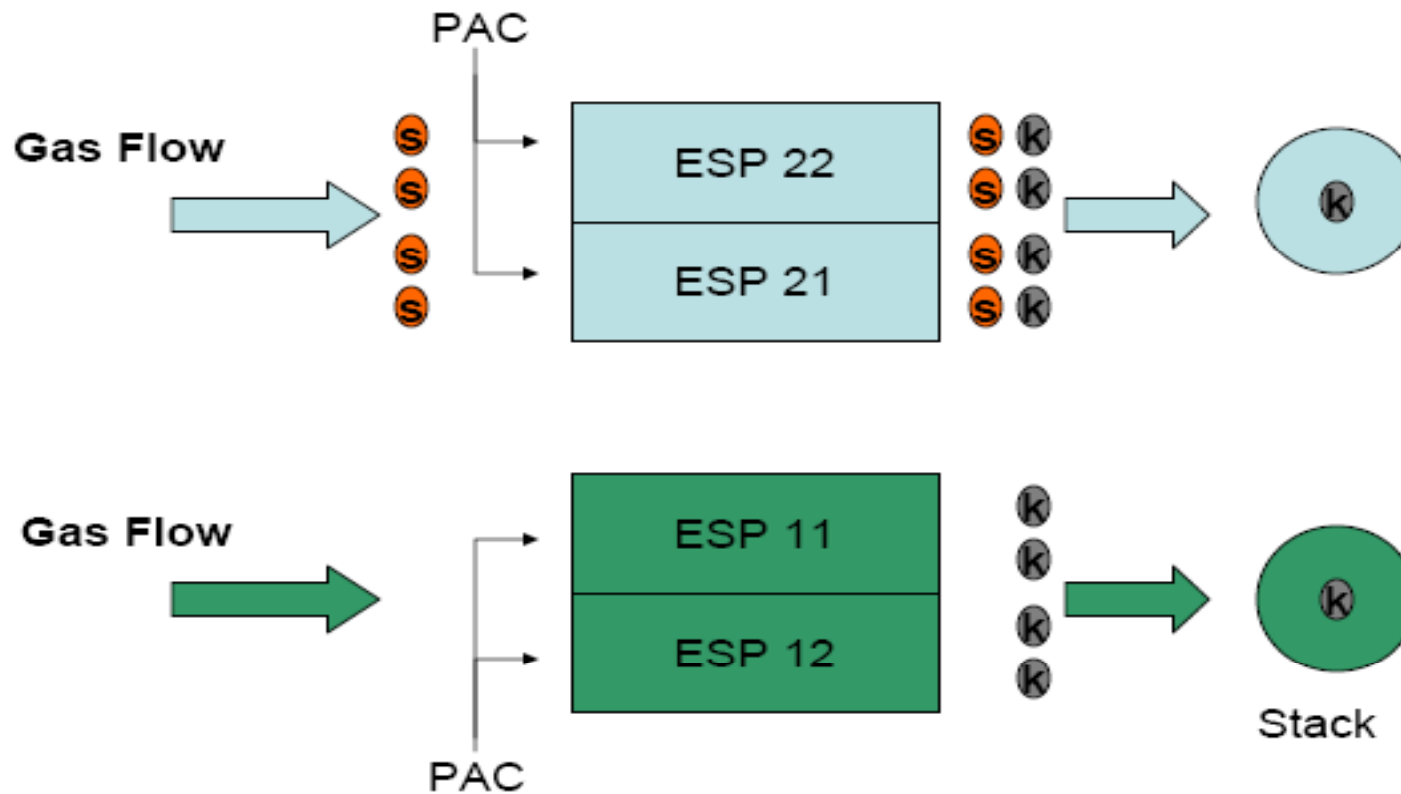
Mer-Cure™ System Technology



- Mer-Cure™ uniformly injects on-line processed sorbent upstream of the air preheater.
- These approaches are covered by several Alstom Patents



Units 1 and 2 General Arrangement



- S** SCEM Measurement (Parametric)
- K** Modified Appendix K Measurement (Parametric, Long-Term)

Sorbent Injection with ESP or SDA/PJFF Mercury Removal Examples



ACI with ESP



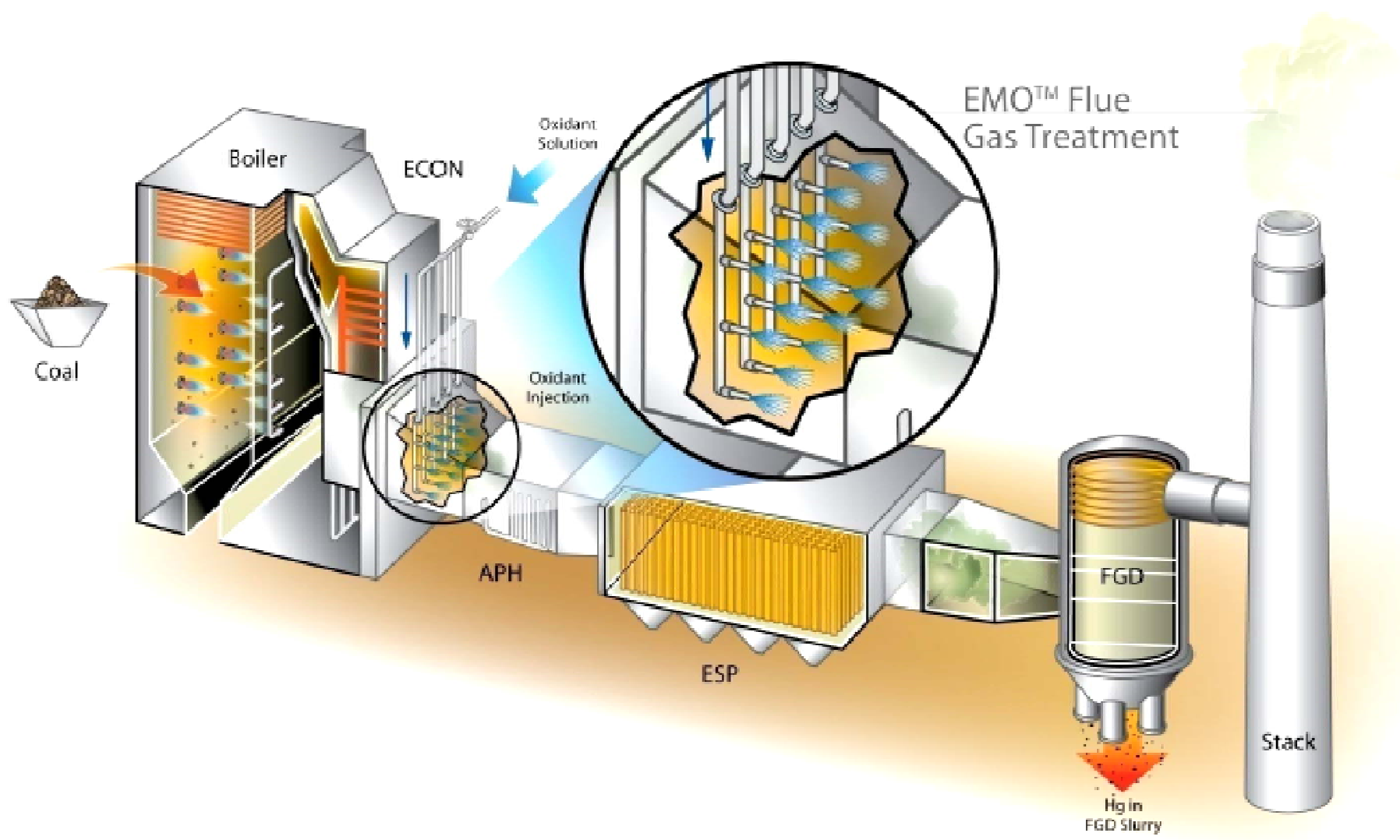
ACI with SDA/PJFF

Fabric Filter (PJFF) with Activated Carbon Injection (ACI) Particulate Matter Removal - Example



ACI with PJFF

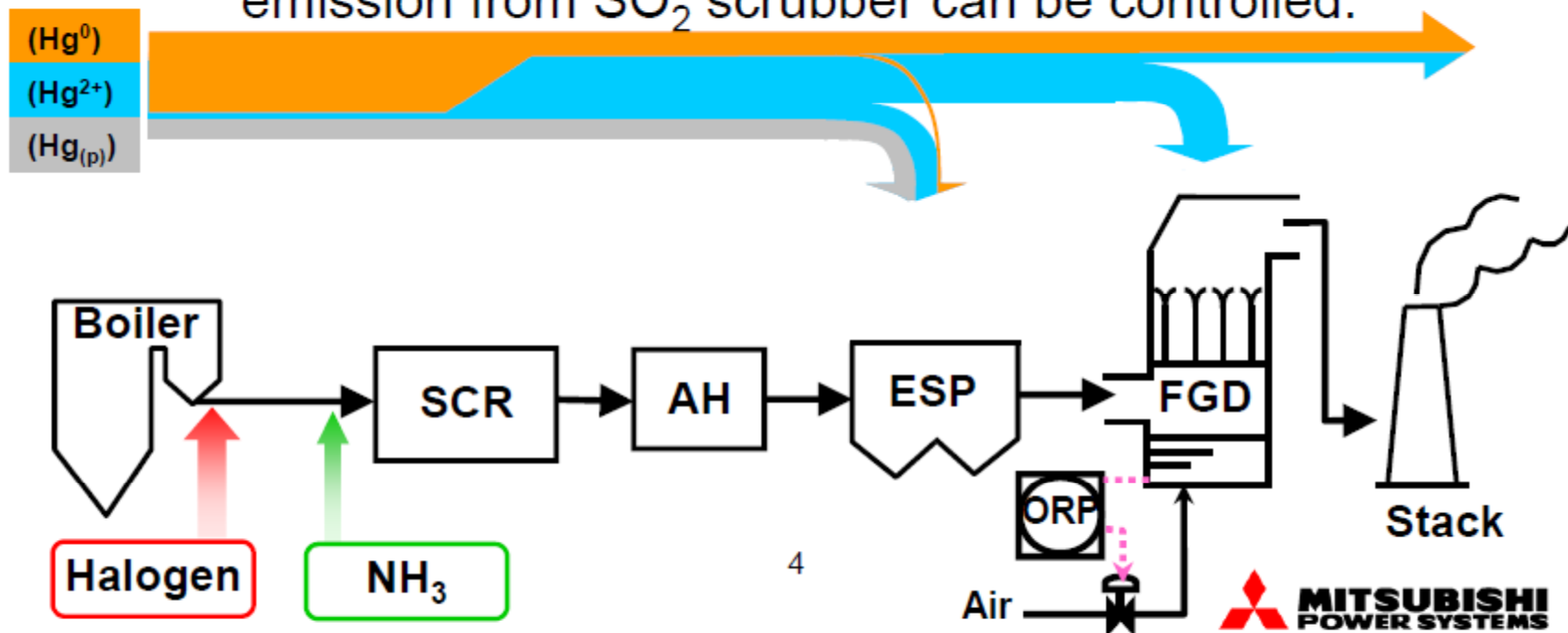
EMO™ Illustration



Mercury treatment system (with SCR/FGD)

- Halogen Injection System

- ✓ Halogen (NH_4Cl) is injected upstream of SCR to oxidize mercury so that it can be taken out by wet scrubber system.
- ✓ With proper scrubber chemistry control, Hg re-emission from SO_2 scrubber can be controlled.





Hg Re-emission across wFGD

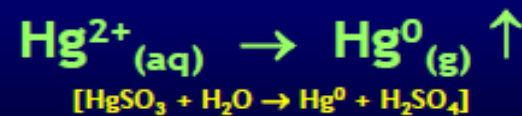
- Wet FGDs are capable of 90+% capture of oxidized Hg.
- Then why is the observed range 50-80% capture?
- What limits compliance of EGUs with this configuration?

Hg Speciation

Hg Re-emission

Definition:

$$[\text{Hg}^0]_{\text{stack}} > [\text{Hg}^0]_{\text{wFGD inlet}}$$



Suggested Reading:

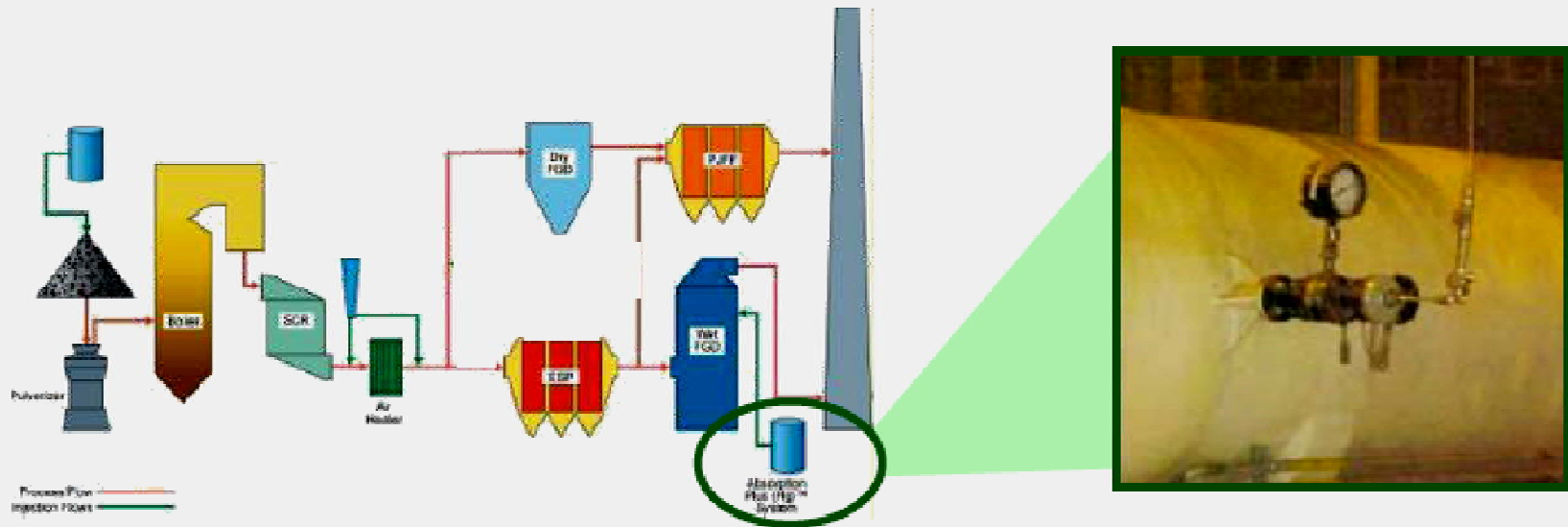
"Bench-scale Kinetics Study of Mercury Reactions in FGD Liquors" Blythe, G. M.; DeBerry, D. W.; April 2007.

"Preventing Mercury Re-emissions in wet Flue Gas Desulfurization Scrubbers at Coal-fired Power Plants using MerControl® 8034 Additive" Stiles, R.L.; et al. Preprints of Symposia - American Chemical Society, Division of Fuel Chemistry (2010), 55(1), 164-166..

"Demonstrating Mercury Emissions Reduction Cost Management" Meier, J.; Keiser, B.A.; and Higgins, B.; Air Quality VIII, Arlington, VA; 2010.

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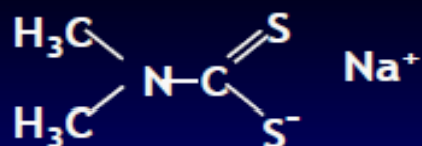
Absorption Plus (Hg)TM System for Enhanced Mercury Capture



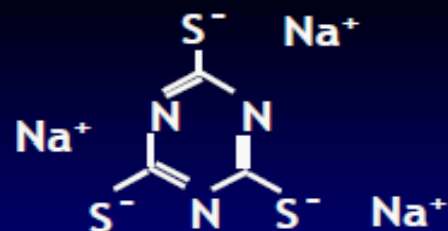
- **Proprietary technology from B&W prevents mercury re-emission from Wet FGD**
- **Removes and retains over 95% of oxidized mercury in FGD**



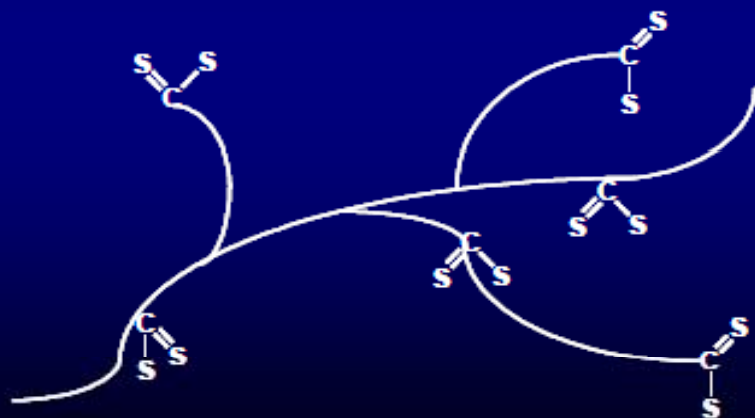
Chemistry of Mercury Chelants



Dimethyl dithiocarbamate
(DTC)



1,3,5-triazine-2,4,6(1H,3H,5H)-trithione
Trimercaptotriazine (TMT)



MerControl 8034 Technology

*(poly-dithiocarbamate)
Patented Technology*

FGD CPS WWTS Sludge (includes mercury removed from waste water)



Sludge may be produced from the clarification of the influent suspended solids to the FGD wastewater treatment system.

Hypothetical composition of generic FGD WWTS sludge:

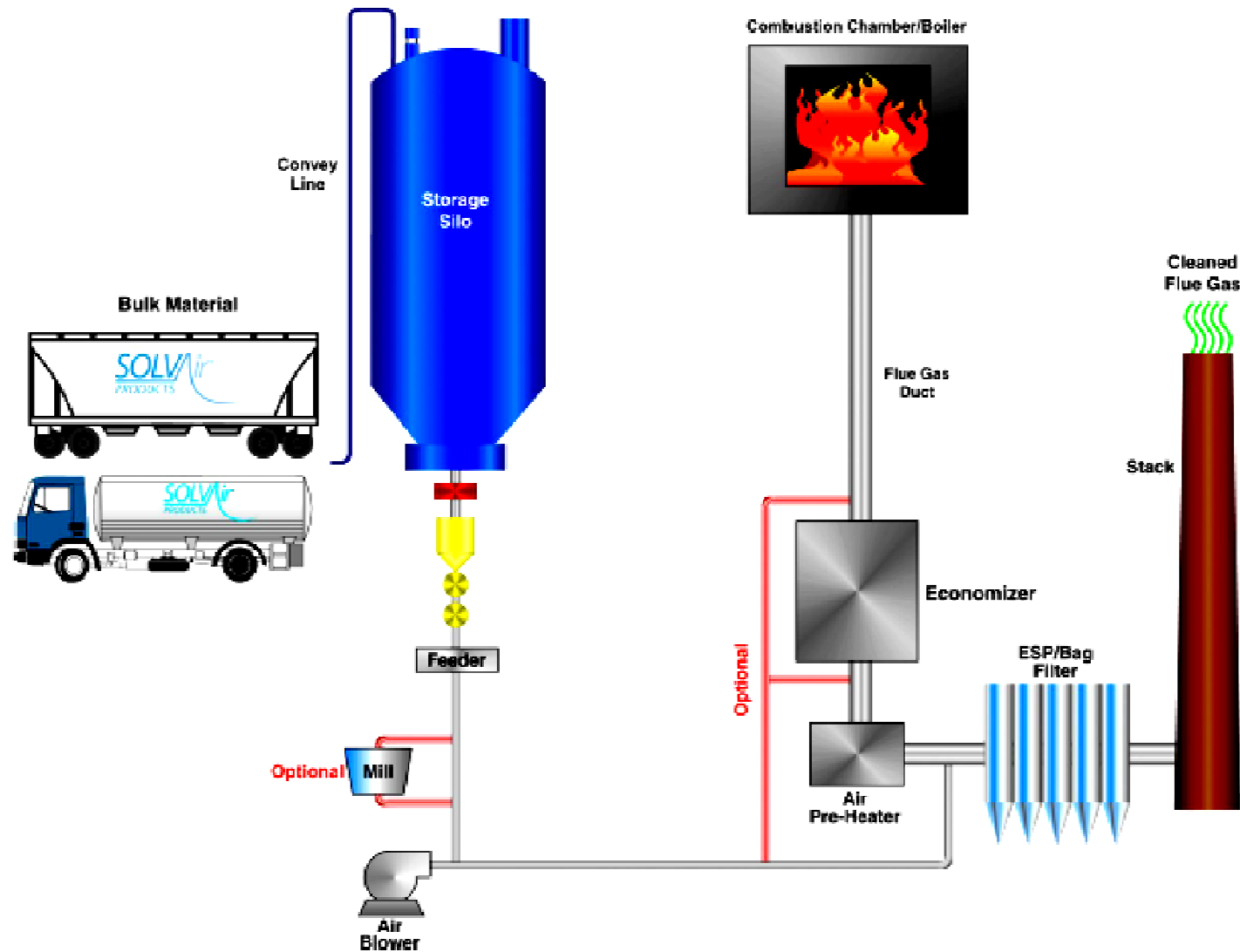
Calcium sulfate	–	78.0%
Limestone inerts	–	4.7%
Calcium carbonate	–	1.9%
Flyash	–	0.9%
Biosolids	–	1.6%
Metal hydroxides & sulfides, etc	–	12.9%



**Acid Gases Control - DSI
(HCl, HF, HBr)**



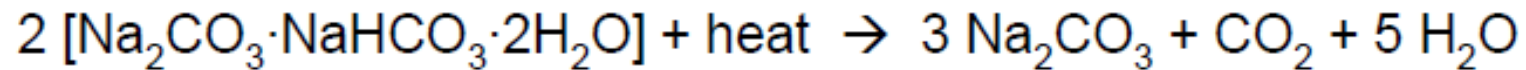
Example of a Utility DSI System



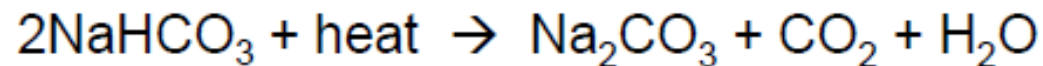
Sorbent Calcination Chemistry



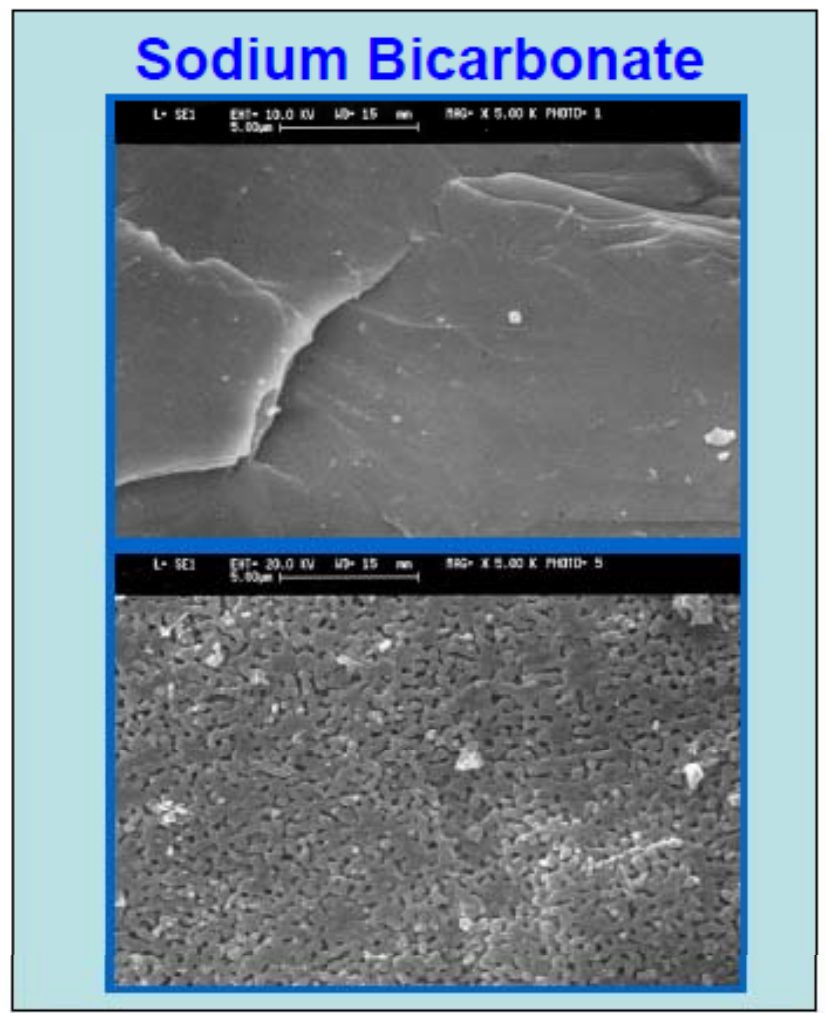
- Calcination of Trona



- Calcination of Sodium Bicarbonate



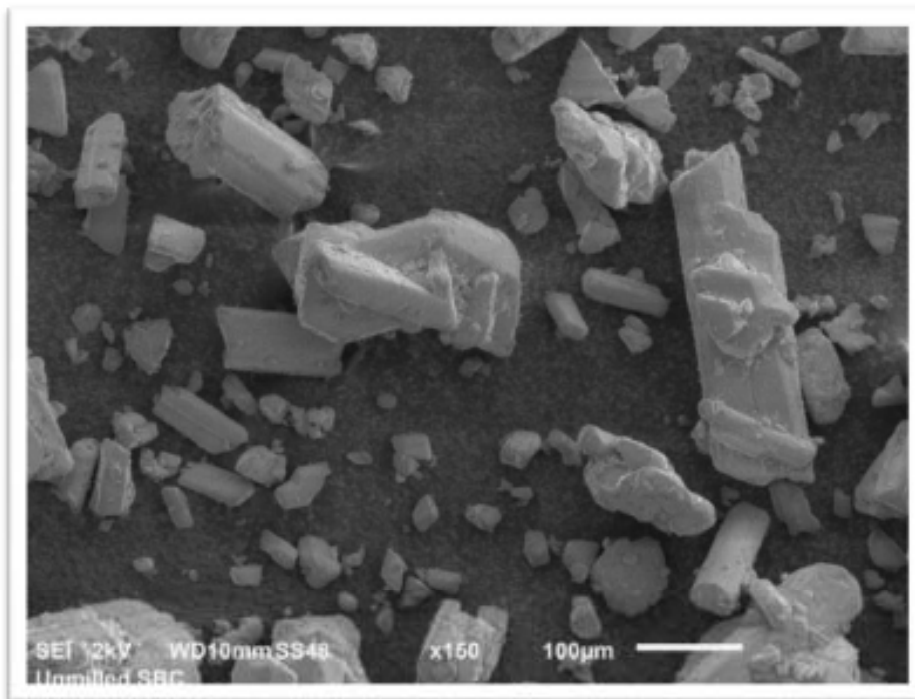
SOLVAir® Select Products: Calcination at >275°F



SBC Particle Size

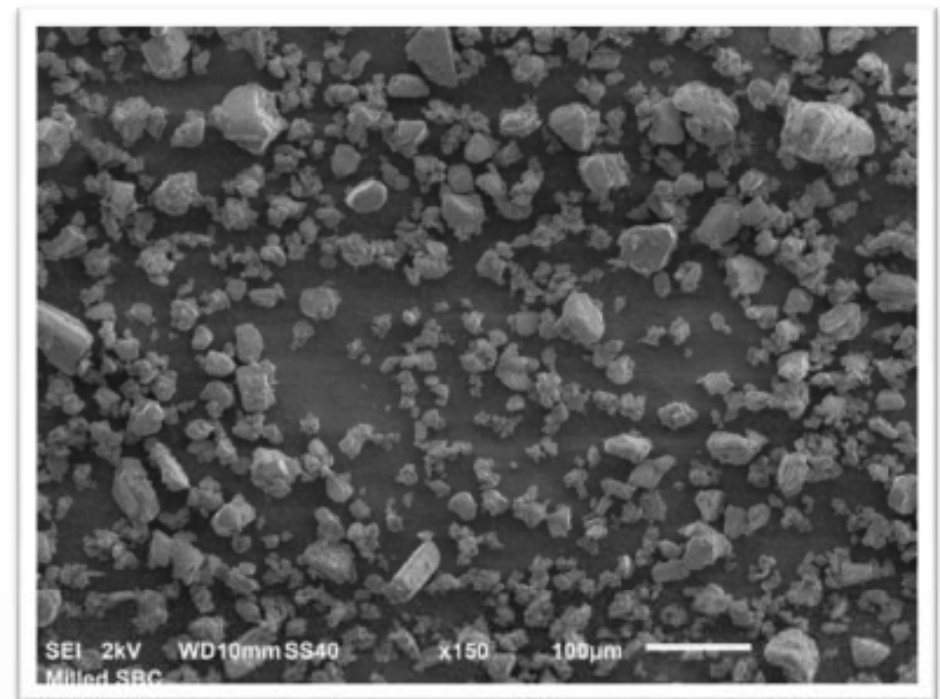


Unmilled SBC



150-180 μm

Milled SBC

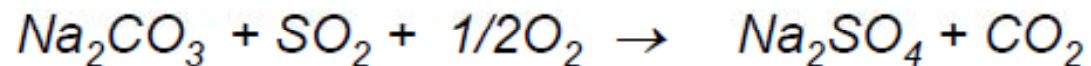


15-19 μm

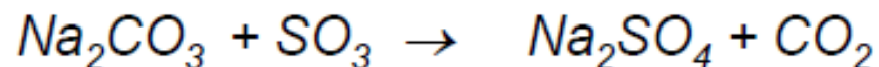
Acid Gas Reactions – Sodium Reagents



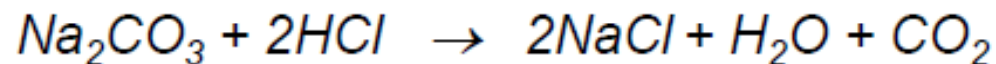
- ***SO₂ Removal***



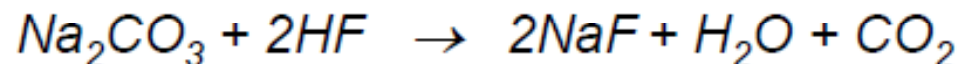
- ***SO₃ Removal***



- ***HCl Removal***



- ***HF Removal***



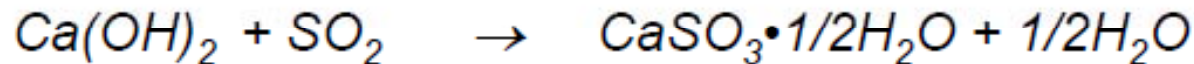
Fly Ash Considerations

- Higher sodium content in the fly ash
- Ash from SO_3 treatment may be okay to market
- Ash from SO_2 treatment typically not suitable for applications in concrete or structural fill
- Solubility of sodium compounds in the fly ash (i.e. Na_2SO_4 , Na_2CO_3)
- Additional heavy metals capture in the ash
- Disposal issues should be investigated early in the process; check properties and work closely with ash marketers.

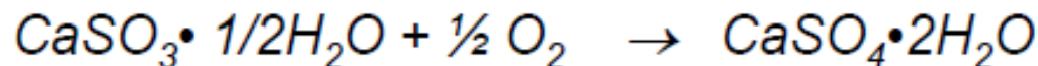
Acid Gas Reactions – Calcium Reagents



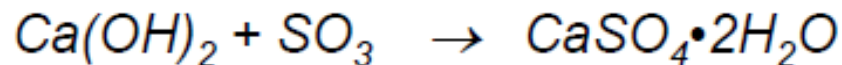
- ***SO₂ Removal***



- ***Sulfite Oxidation***



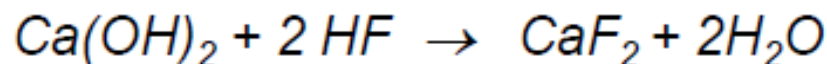
- ***SO₃ Removal***



- ***HCl Removal***



- ***HF Removal***



Other Acid Gas Chemical Reactions

✓ *HF Removal*



✓ *SO₃ Removal*



✓ *HCl Removal*



Note – Lhoist has demonstrated in multiple tests Hydrated Lime reacts more strongly (or quickly) with HF, then SO₃, then HCl.



$$\text{NSR} = \frac{\frac{100 \text{ LBS/HR}}{50 \text{ LBS/HR}}}{(74.12 \text{ MW} / 64.10 \text{ MW})}$$

$$\text{NSR} = 1.72$$



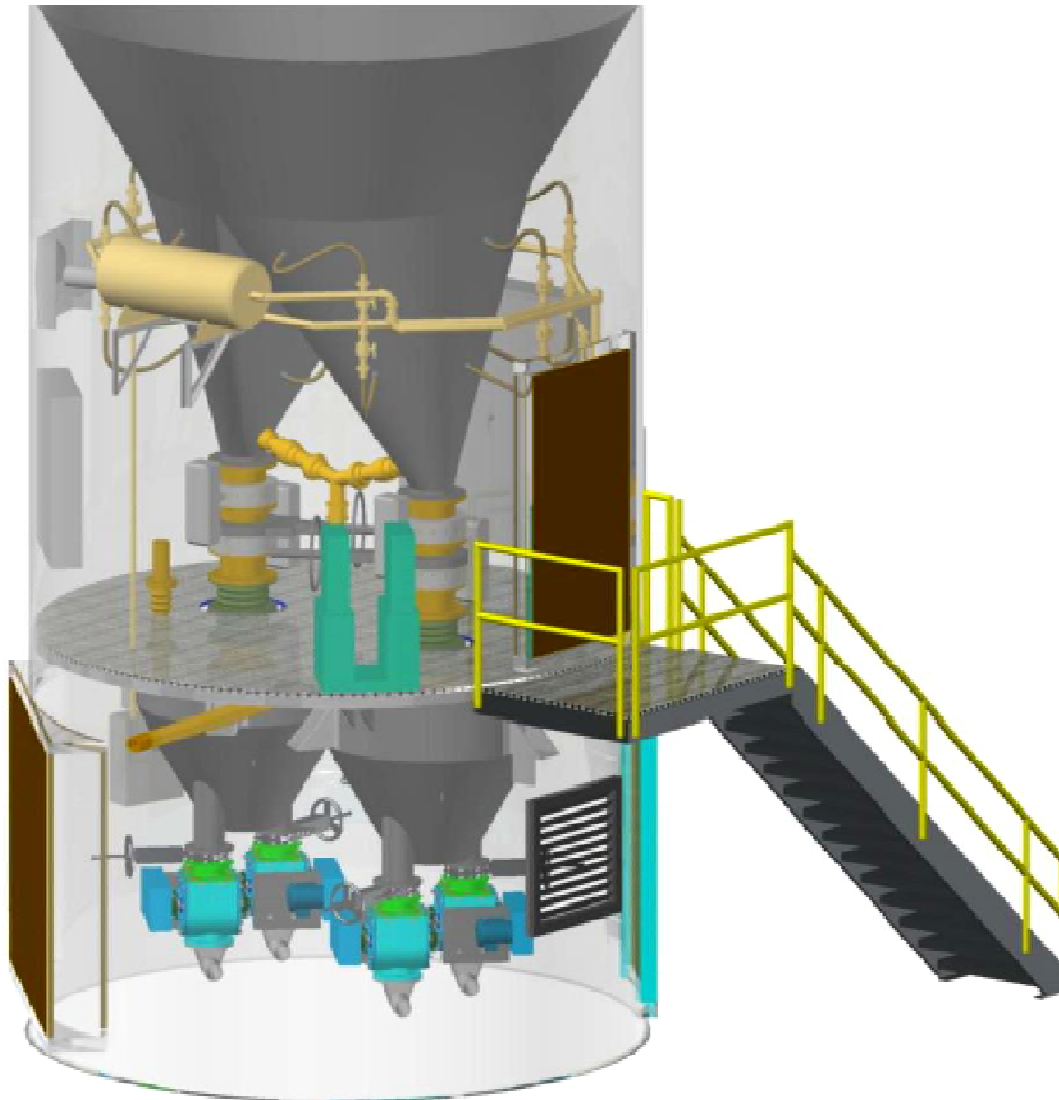
$$\text{NSR} = \frac{\frac{100 \text{ LBS/HR}}{50 \text{ LBS/HR}}}{[74.12 \text{ MW} / (2 * 36.46) \text{ MW}]}$$

$$\text{NSR} = 1.96$$

$$\text{NSR} = \frac{\frac{\text{Mass of reagent injected}}{\text{Mass of acid gas entering system}}}{\text{Mass of reagent theoretically needed to react with a unit mass of acid gas}}$$

	MW
Na ₂ CO ₃ (HCO ₃)?2H ₂ O	226.03
NaHCO ₃	84.01
Ca(OH) ₂	74.12
SO ₂	64.10
HCl	36.46

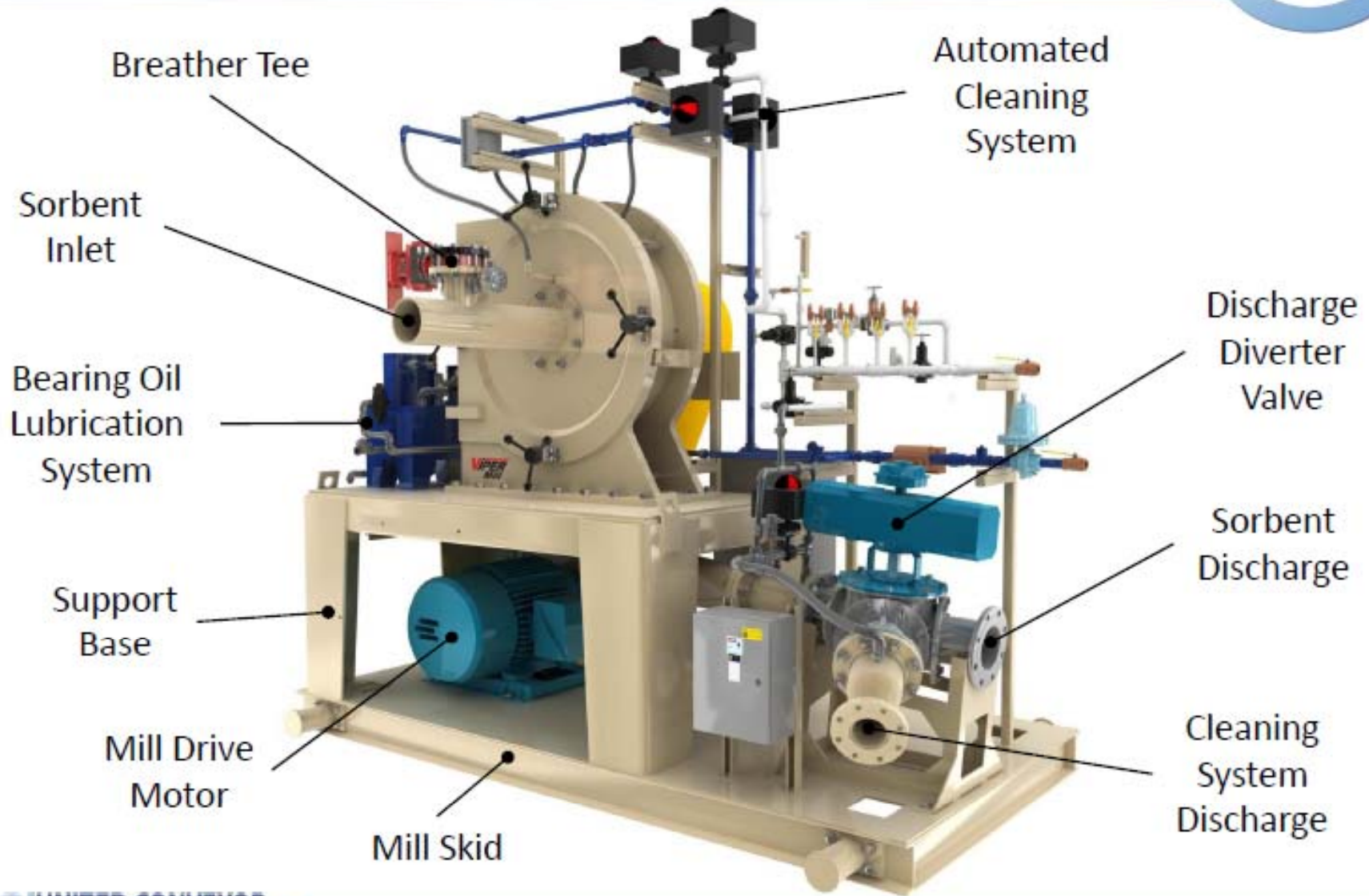
DSI System: Pre-Installed Arrangement



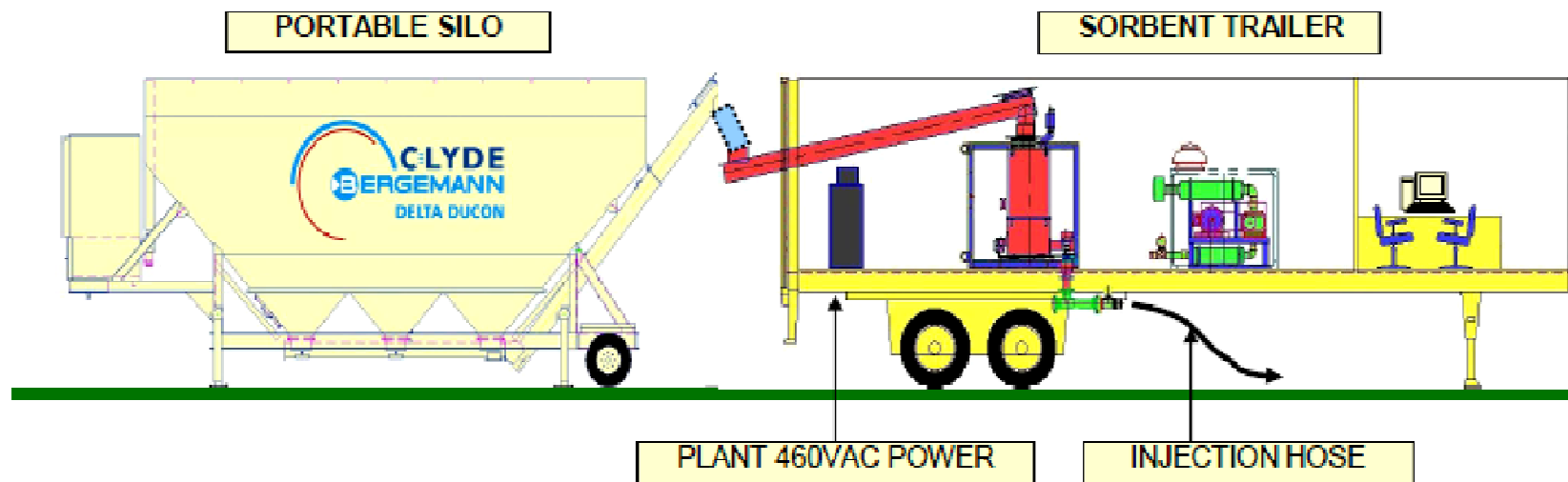
- **Second Equipment Level:**
 - Increased maintenance access
 - Location of electrical panels
 - Stairway and external platform provided
- **Weigh Hoppers:**
 - Suspended from second floor steel to provide increased maintenance access
 - Multiple feeders to provide redundancy
 - Sized to reduce cycles on refill valves

VIPER™ Mill Skid Layout

Summary of Major Improvements



Portable Sorbent Injection System



- Mobile system designed to test and demonstrate emissions control systems at a plant through injection of a variety of sorbents into gas stream including:
 - Powder Activated Carbon (PAC) for mercury control
 - Trona (Sodium Sesquicarbonate) for SO_x and HCl control
 - Hydrated lime for SO_x and HCl control
- Full system consists of a portable material storage silo and a sorbent control trailer
 - Trailer utilizes various feeders, eductors, and blowers to ensure proper metering of sorbent

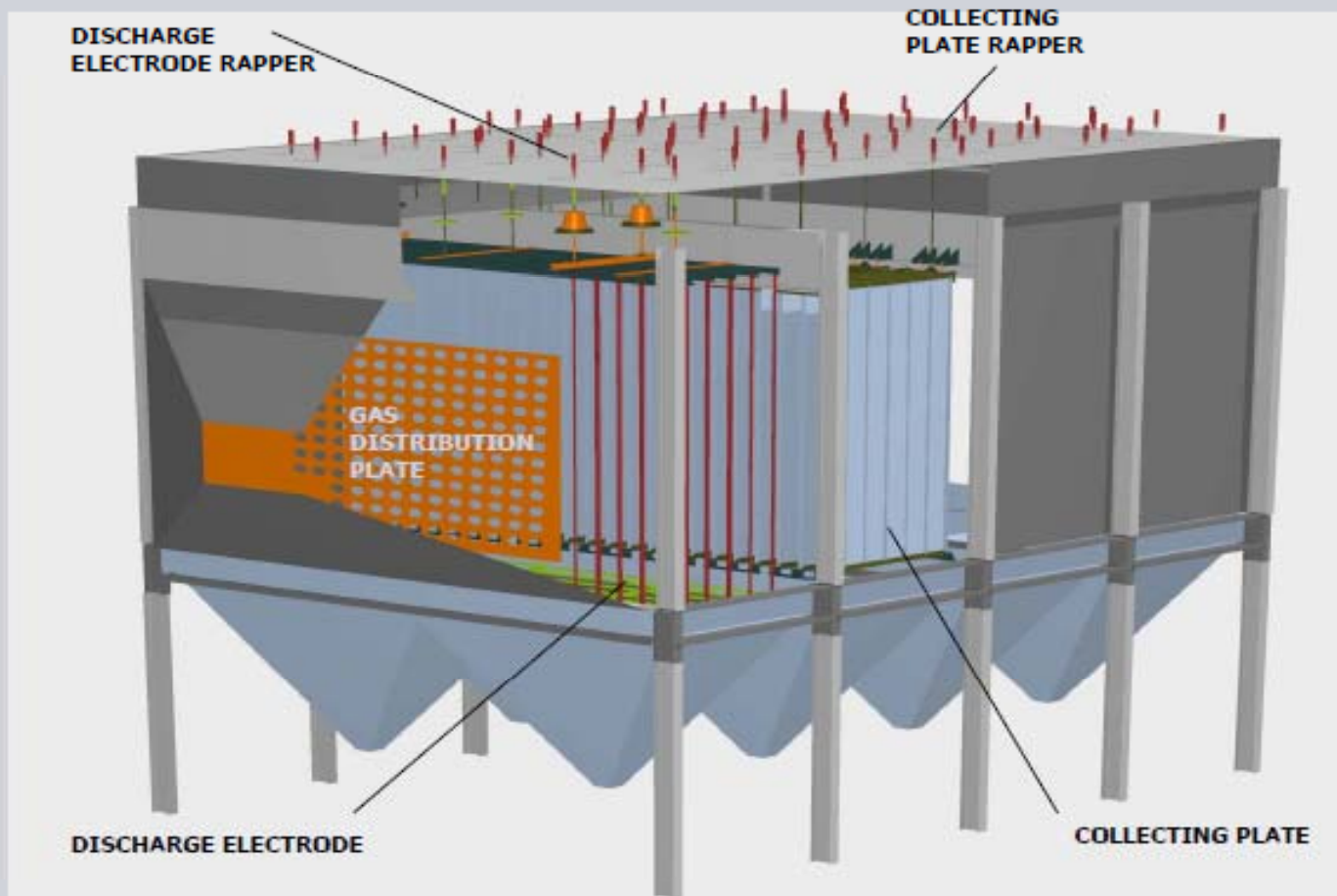


**Particulate Matter Control
(TPM, PM-10, PM 2.5, SO₃/H₂SO₄)**



Variable Intensity Gravity Rapped (VIGR) Precipitator

SIEMENS



CUTAWAY SHOWING INTERNALS



ESP Performance Improvement



Enhancements to Existing ESP

- Are the internals aligned?
- Are all rappers working?
- Are T/R controllers working and optimized?
- Are T/R signals calibrated and working at controller?
- Are all meters working?
- Is ash removal system working?
- Are all insulators clean?
- Have any leaks been eliminated?

Improvements 5-10% dependent upon work done

ESP Upgrade Options

Typical Scope

Options for Upgrading ESP's to Meet Specific Emission Requirements

Improve Gas Distribution

- CFD/physical model study
- Modify gas distribution devices
- Address sneackage, casing leaks, etc.

Increase SCA

- Add treatment length
- Use inter-field space (rigid frame designs)
- Increase collecting plate height

Change electrode geometry

- Replace plates &/or change plate spacing
- Change discharge electrode design (RDE's)

Improve Field Sectionalization

- Consider splitting electrical fields
- Add additional T/R's

Upgrade rapping systems

- Change rapper design
- Increase rapper sectionalization
- Install additional rapping, if necessary
- Upgrade Controls

Install Improved Control Systems

- EPIC III AVC's
- ERIC Rapper controls

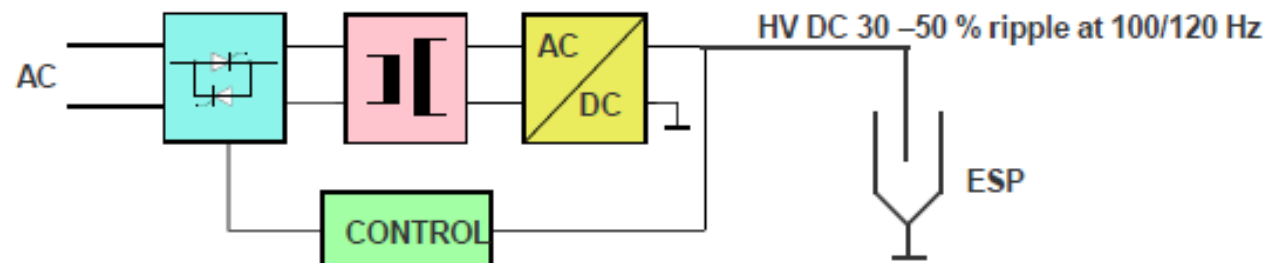
Replace Conventional T/R's

- SIR (Switched Integrated Rectifiers)
 - Increase average field voltage
 - Improve collection efficiency

Electrostatic Precipitator Components

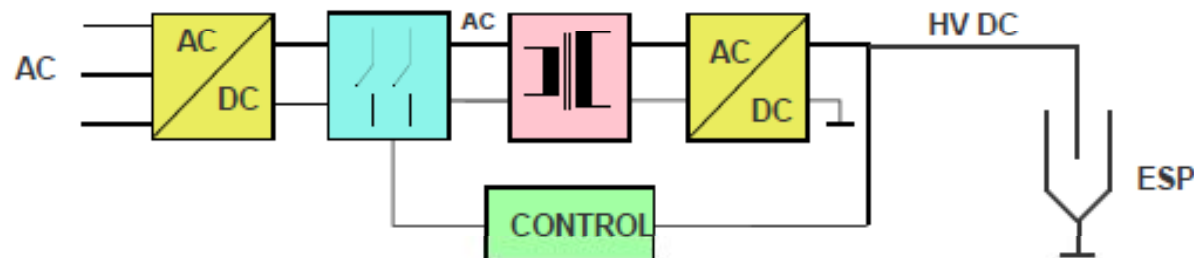
Power supply (T/R set vs. SIR)

Line frequency power processing



High frequency power processing

Controller varies frequency between 25 and 40 kHz



Electrostatic Precipitator Components

Power supply (T/R set vs. SIR)

**Mains frequency
power supply**



400 lb + 3200 lb

**High frequency
power supply**



450 lb



NWL PowerPlus

01M042012D

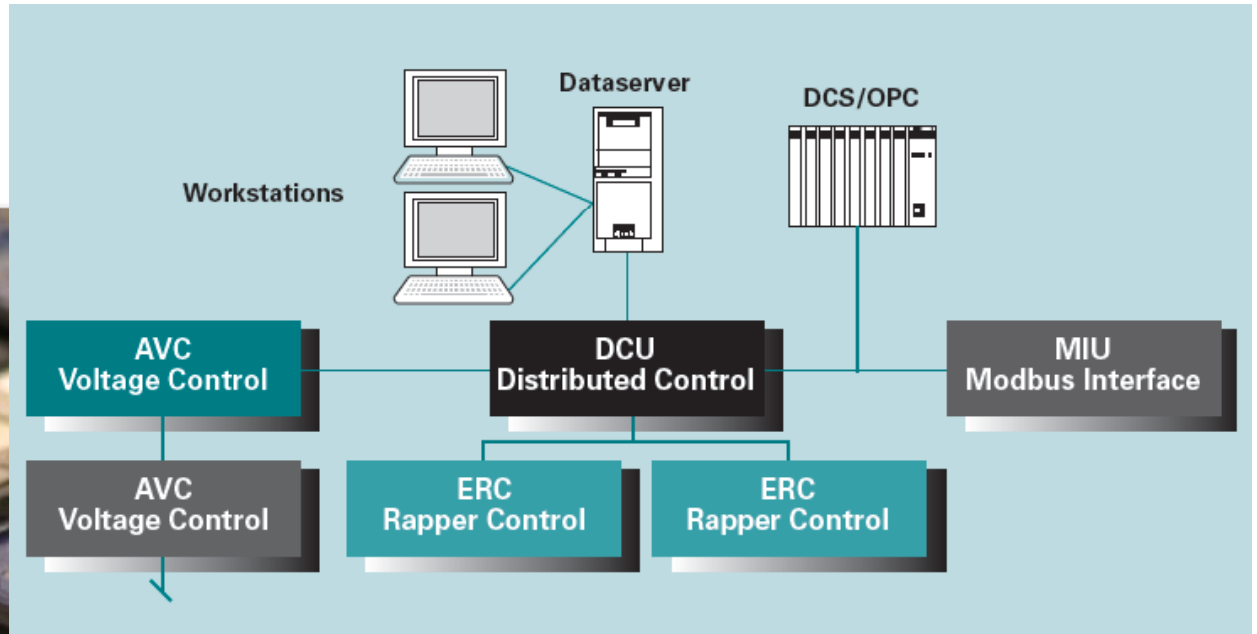
AQCS TECHNOLOGIES (HG/HCL/PM/SOX/NOX)

72

ModuPower™

for ESP Applications

A Stock Environmental Controls Product



Forry Integrated Precipitator Management Solutions



Automatic Voltage Control

- Microprocessor Automatic Voltage Controls
WAPC - 2000 TM
 - Easy to Use, Service & Maintain
 - Intermittent Energization Capable
- Central Computer Control / Energy Management System
WAPC - CCC TM
 - Capable of Energy Management
 - Real Time Data Acquisition & Trending
 - Trending
 - Monitor & Control ESP Auxiliaries
 - Auto Response To Upset Conditions
 - MODBUS Interface With Plant DCS





10/05/2007

General layout

The FF consists of a number of component groups

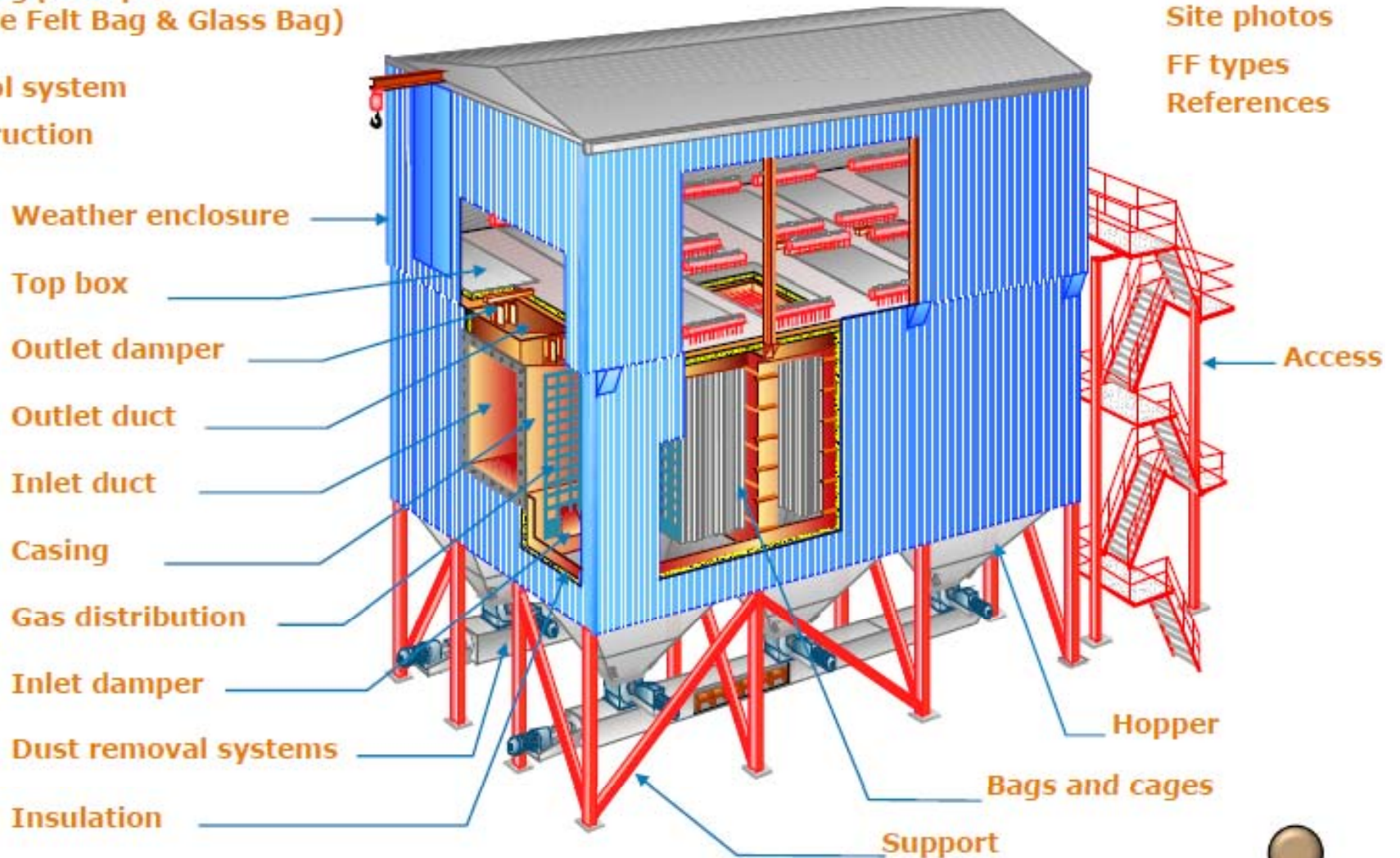


Cleaning principle
(Needle Felt Bag & Glass Bag)

Control system

Construction

- Highlights
- Site photos
- FF types
- References



Safety, Quality, and Schedule with Modular Construction



PJFF Installation



Safety, Quality, Schedule, and Construction



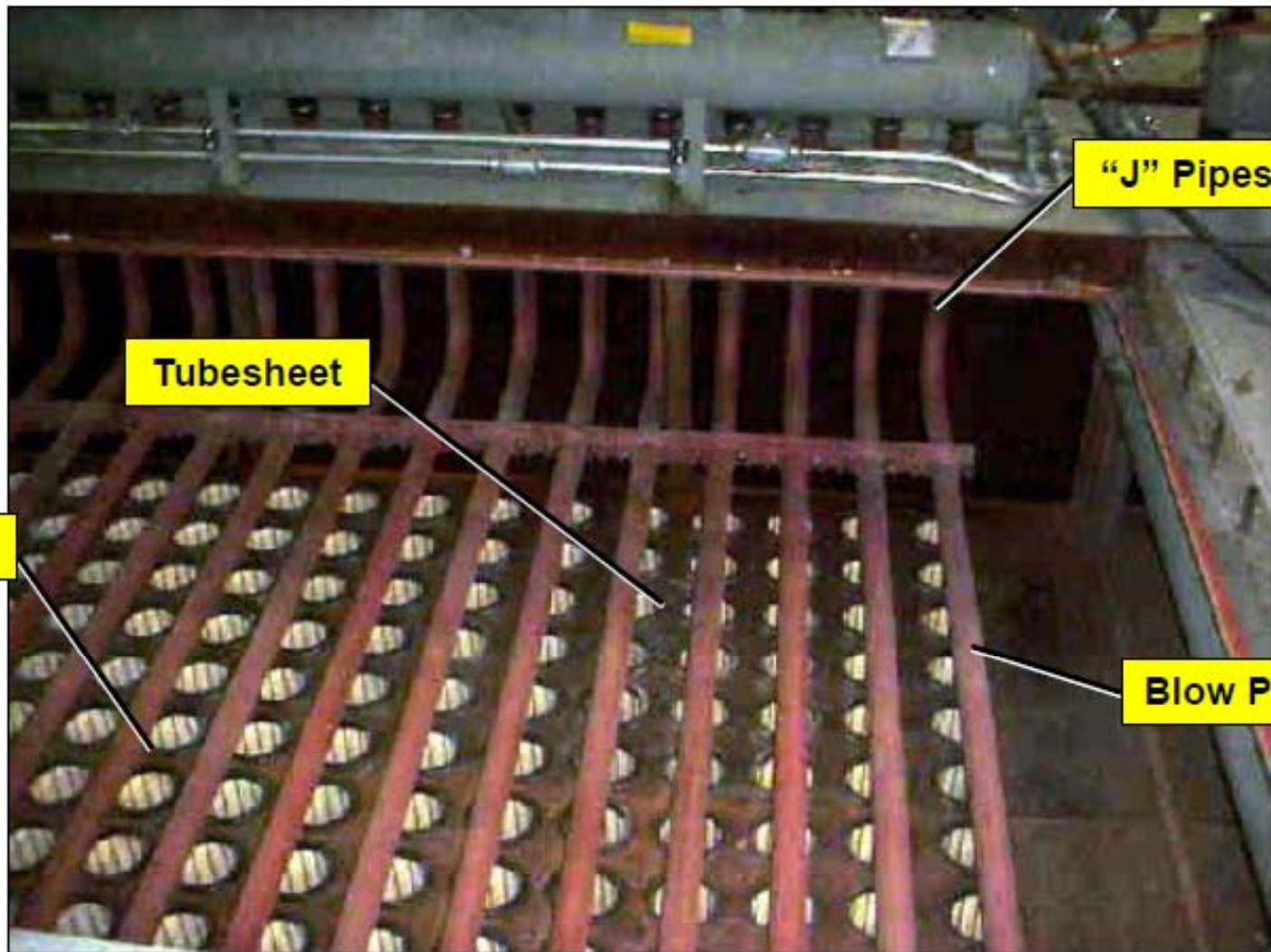
PJFF Installation with CDS



PJFF Installation with CDS

Pulse Jet Baghouse

(Tubesheet and Pulse Air System)



Bags

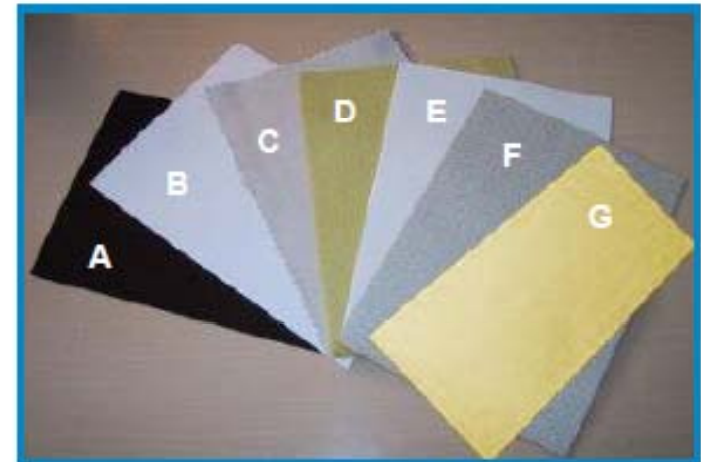
Each filter bag incorporates a stainless steel snap ring sewn into the top of the bag which, when fitted, locates securely in the tube sheet effecting a seal.



Installation



Snap ring



Bags pre-erected with cages
Up to 8 m bag design

Correct bag/cage fit is
Essential for long bag life

Typical bag material	Temperature limits °C
A: PTFE needle felt	260 = 500F
B: PPS needle felt	190 = 374F
C: Woven glass with e-PTFE membrane	260 = 500F
D: Polyimide needle felt	240 = 464F
E: Polyester needle felt	150 = 302F
F: m-Aramid needle felt	200 = 392F
G: Pan	125 = 257F



Cages



Return to
Cleaning princp.



Return to layout

PTFE Bags

Improving Fabric Filtration Efficiency with ePTFE* Membrane expanded Polytetrafluoroethylene



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Polytetrafluoroethylene (PTFE) is the chemical name for a compound developed by Dupont in the 1940s. You know this product as Teflon® which is commonly used for a non-stick surface on cookware, Teflon plumbing tape, etc.

(ePTFE) is expanded PTFE which is Teflon that's been stretched into a thin membrane that's then laminated to the collection surface of a base filtration media. Base filtration medias could be polypropylene, polyester, acrylic, fiberglass, aramid fabrics such as aramic, PPS, P84 or a base media also manufactured out of Teflon. In a coal fired plant, the filters are fiberglass for reverse air baghouses and usually Polyphenyl sulfide (PPS - Ryton / Torcon / Procon) in pulse jet baghouses.

Cages



The cage mild steel wire (or stainless steel) is designed to support the fabric evenly and restrict flexing and abrasion of the filter bag while allowing optimum dust release at the time of cleaning. The cage will be without joints as standard, but can be offered with a split joint if required. Each cage consists of 10 to 16 vertical wires, depending of the choice of the fabric, evenly spaced about its' circumference which are, in turn, attached to horizontal bracing rings placed at appropriate intervals along its' length.



Split Cages



A feature of each cage is a venturi, a spun section located at the top of the cage designed to enhance the pulse cleaning of the filter bag



Cage for Glass Bag

Pulse Jet Fabric Filter FabriClean™

Cage for Needlefelt Bag

July 14, 2012



Different styles of surface protection are available. (Epoxy, galvanized)



Previous



Return to layout

Filter Bag & Cage Installation

Positive Seal Formed By SS Snap Ring Sewn Into the Bag, Seated Against the Tubesheet.

“No-Tools” Installation



Advanced Pulse Cleaning

Pulse Cleaning Principle



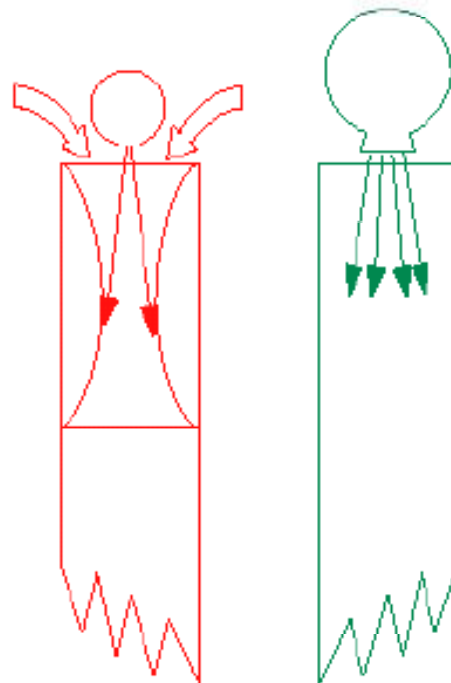
Traditional

High Pressure
50-100 psi

Ejected Pulse

Secondary air
6 - 7 times larger
than primary air flow

- Slow pulse
- Short bag length



Advanced

Intermediate Pressure
15-35 psi

Direct Pulse

Primary air expands direct
into the bag - secondary
air 1 - 2 times the primary
air

- Short and quick pulse
- "Deep" pulse
≡ longer bag length

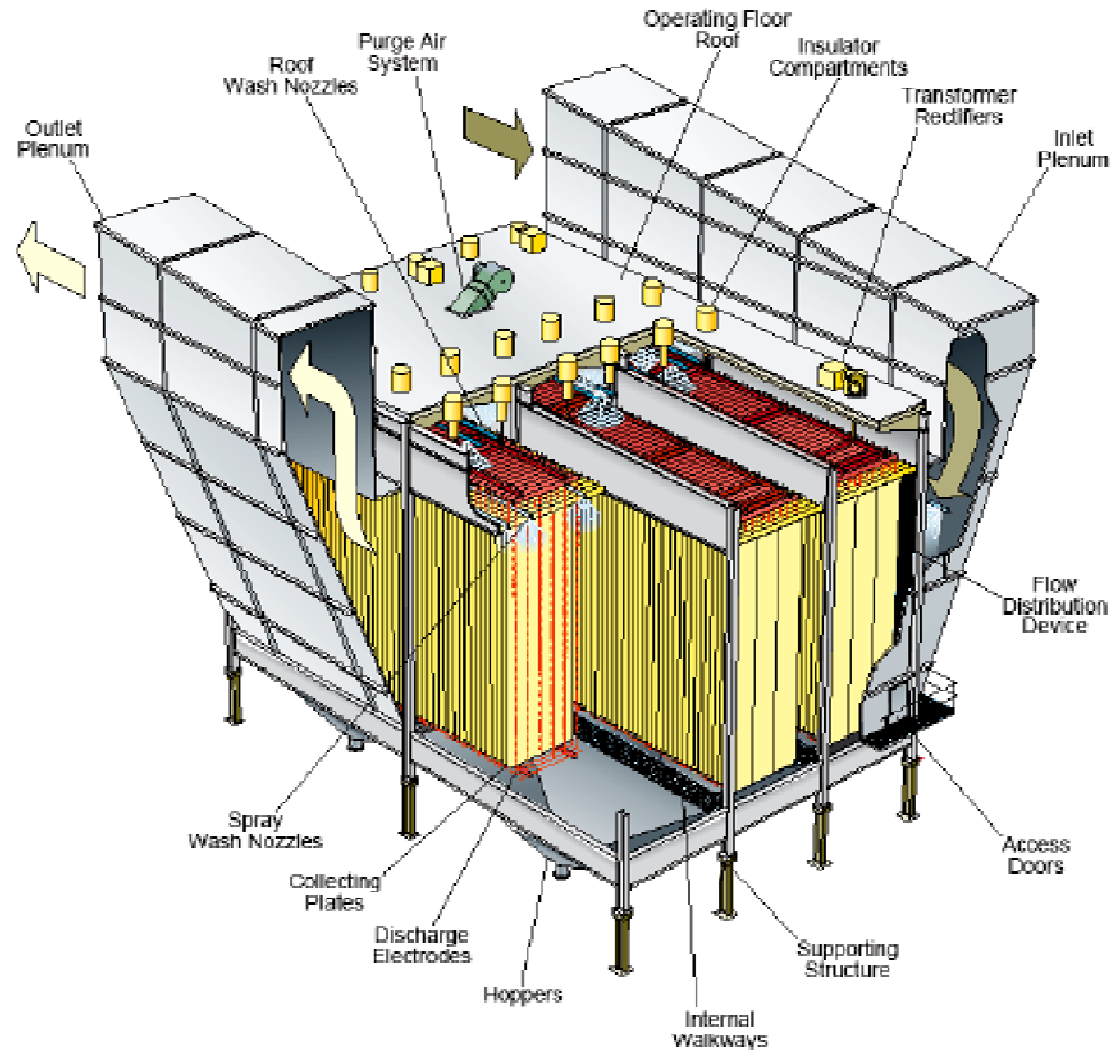
- Filter Bag installation
 - Faster
 - Worker accessible tube sheet
 - Individual bags easily changed
 - Bag sets easily installed
 - Safer
 - No pulse pipes to avoid
 - No pulse pipes to lift/reassemble



ESP to FF Conversion

- **“Typical” ESP designs easily accommodate conversion**
 - ESP gas velocity in range of 3-6 ft/min
 - ESP collecting plate height in range of 30 to 42 ft
 - ESP SCA in range of 200 – 400 ft²CE/1000 acfm
- **“Typical” flue gas flow – 400 MW boiler burning PRB**
 - 10000 BTU/kWh heat rate
 - 1000 ft ASL, 120% CA, 12%APH inleakage, 300F, -20”w.g.
 - Flue gas at ESP/FF inlet = 1,650,000 acfm (5% O₂) (412,500 acfm per 100 MW gross)
- **ESP/FF conversion example – for above “typical” 400 MW unit**
 - ESP configuration 2P, 4C, 31GP@9”, 36ft, 4x9ft
 - ESP is 390 SCA (9”), equivalent 290 SCA (12”), 4.7 ft/sec, 8.8 second treatment time
 - Each 25’x41’ chamber would hold two HRC LPHV bag bundles
 - Either “side” entry or “dutchman” entry could be accommodated
- ESP/FF conversion would be 8 compartments
- Resulting filter velocity for 8m bags is conservative (9m bags could also be used)
 - 3.0 ft/min – gross
 - 3.4 ft/min – net

Horizontal Wet ESP Isometric



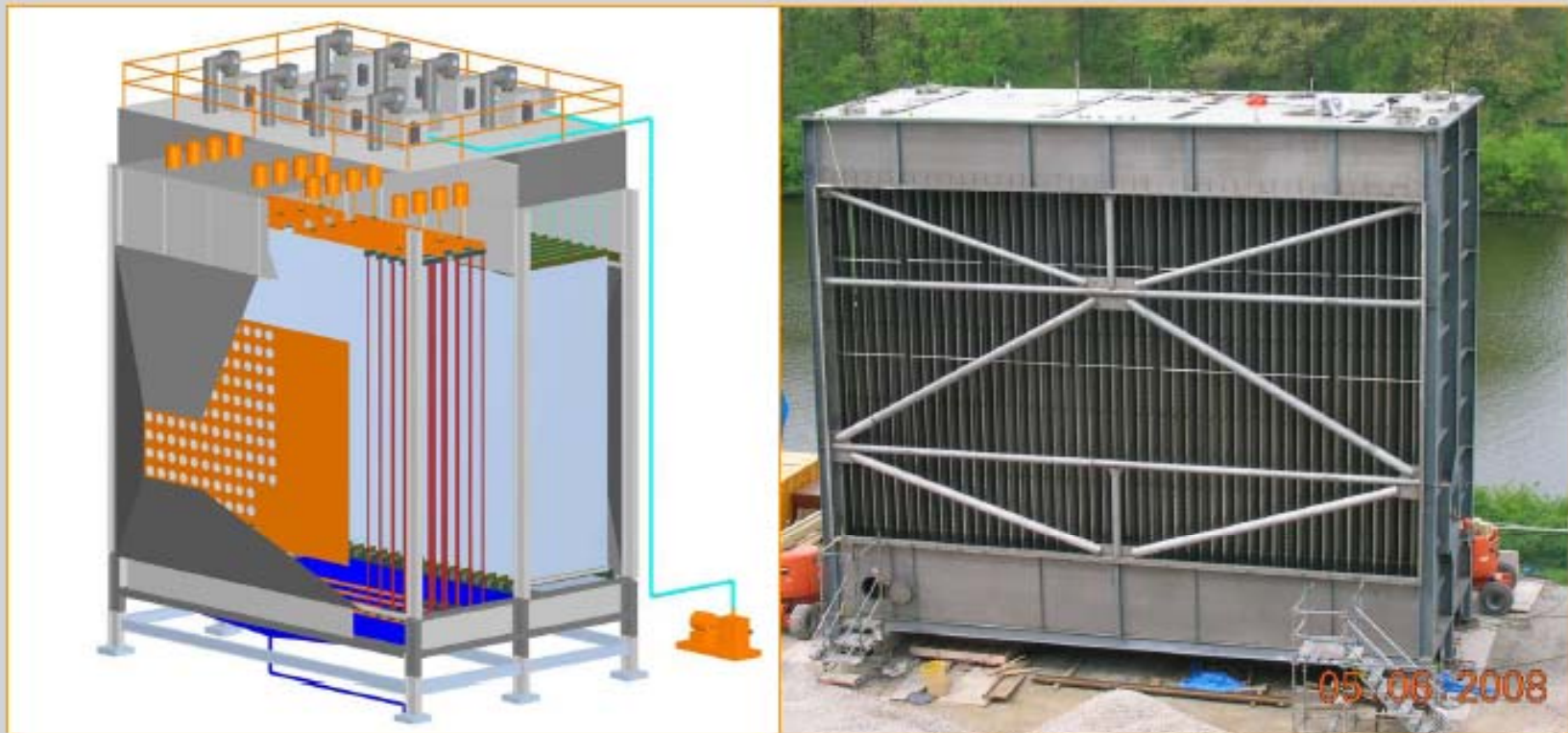
Wet Electrostatic Precipitators

- Achieve lowest emissions for PM & SO₃
- Unique Membrane technology to lower costs
- SEI Turnkey Projects



Siemens Horizontal Irrigated Plate WESP

Wet ESP designed to be a final polishing device to collect sub-micron particulate and mists

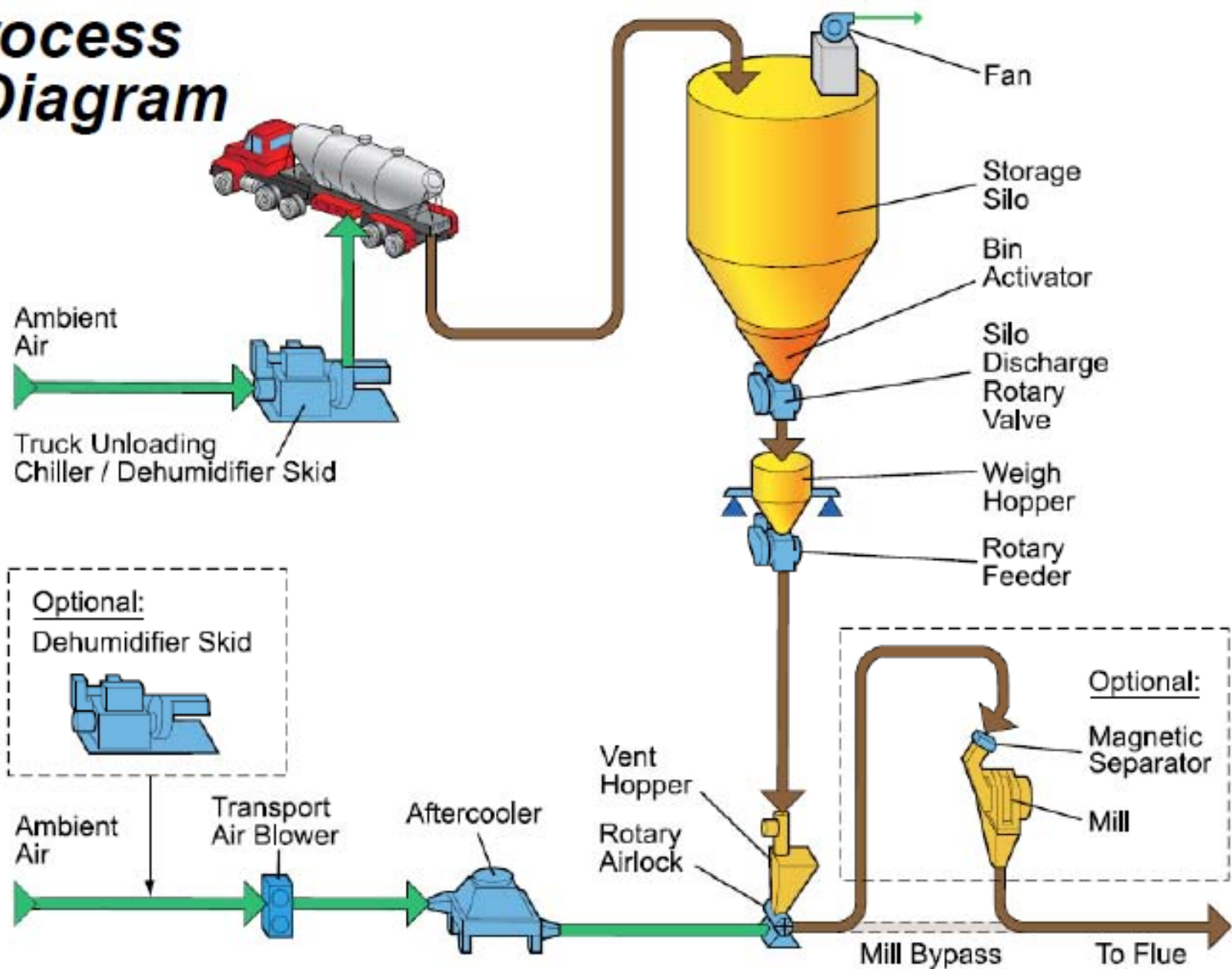




Sulfur Dioxide Control (SO₂)



DSI Process Flow Diagram



Fabric Filter with DSI Trona Injection - Example



Trona Injection DSI FGD-PJFF

Natronx Trona and SBC Summary

- Trona and SBC both have reducing ability at high to low temperatures
 - SO₂ , SO₃ , and acid gases
- Conditioned Air System Benefits
 - Easy of handling
 - Decrease flowability issues
 - More efficient use of material
- Milling before injection increases material reactivity

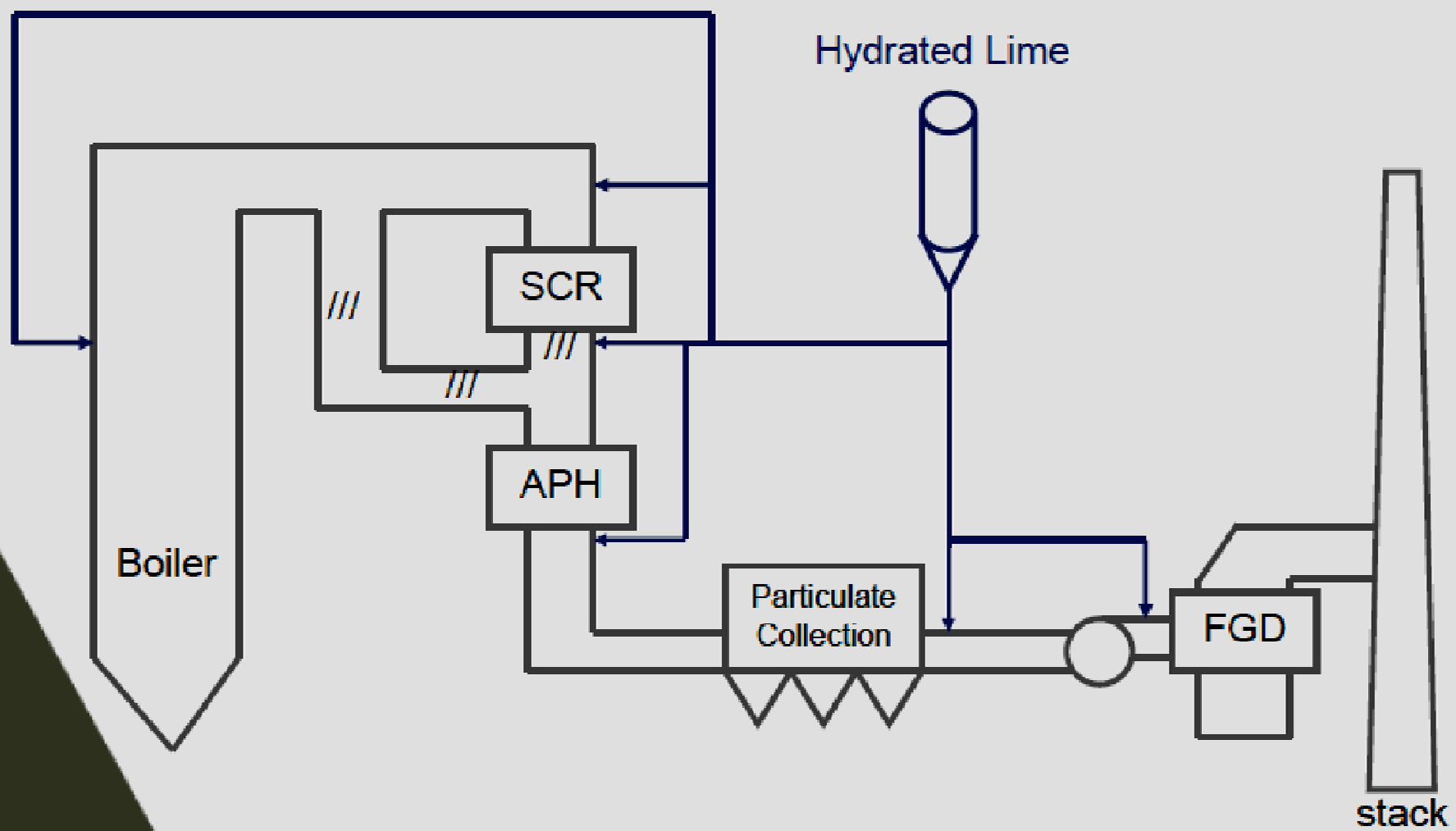


Trona vs. Sodium Bicarbonate Cont'd

- At temperatures around 280 °F to 650 °F (downstream of the air preheater) sodium bicarbonate is more reactive than trona.
- But when used upstream of the air preheater at temperatures in the 700 Deg F to 1000 Deg F range Trona outperforms sodium bicarbonate.



Injection Location Options for Hydrated Lime



Portable Silos

Demo & Temporary / Rental or Purchase



MET SO₃ Control Technology

Cost Effective SO₃ Removal Explained:

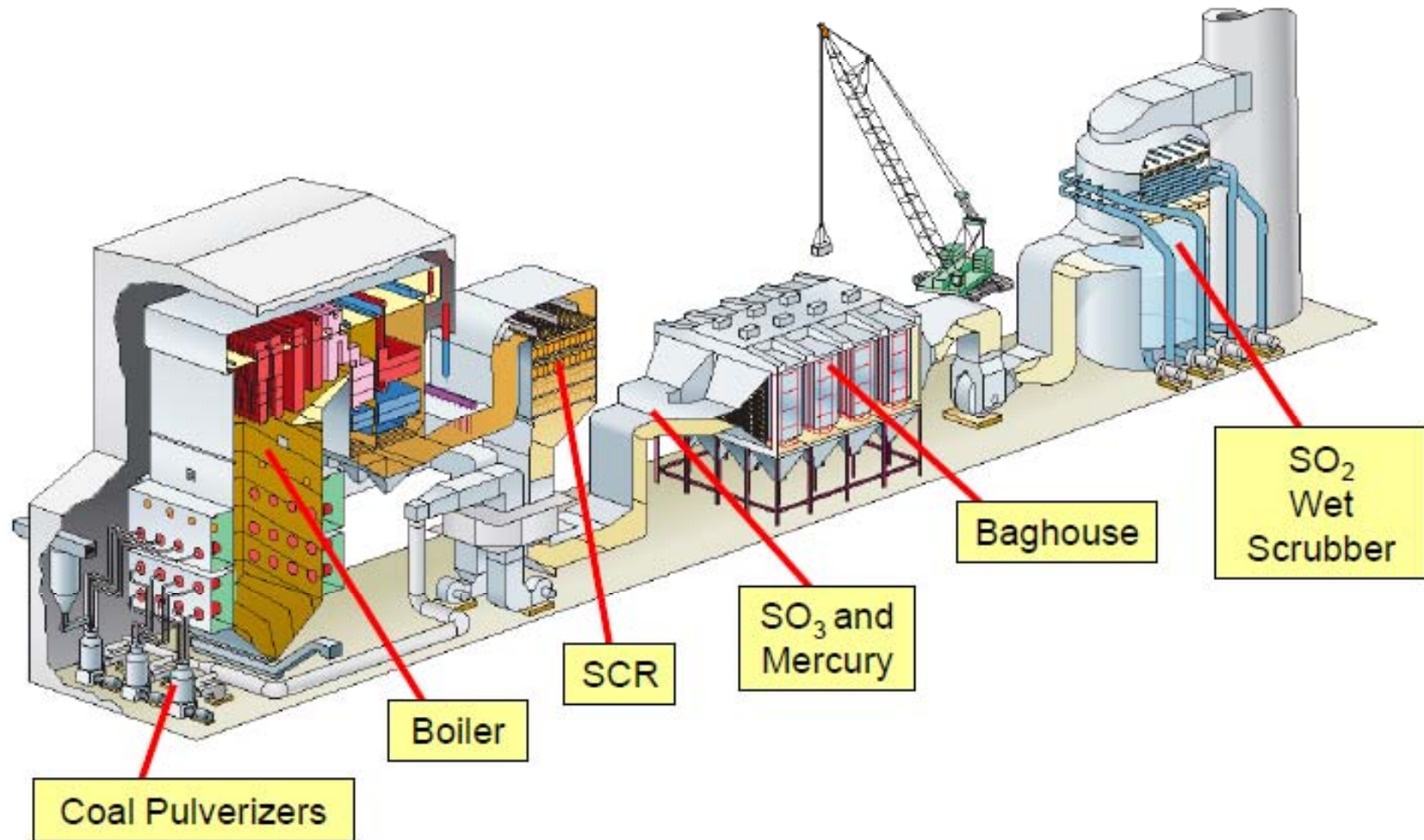
CleanStack®

Within an air preheater:

- Flue gas temperature drops below the SO₃ dew point
- Most SO₃ condensation occurs preferentially on small particles (<4 μm)
- This results in condensed SO₃ removal by the particulate control device (fabric filter or ESP)
- By substantially increasing small particle nucleation sites, SO₃ removal increases
- Use of low cost limestone feedstock provides alkaline neutralization of nucleated H₂SO₄



Typical Wet FGD Configuration

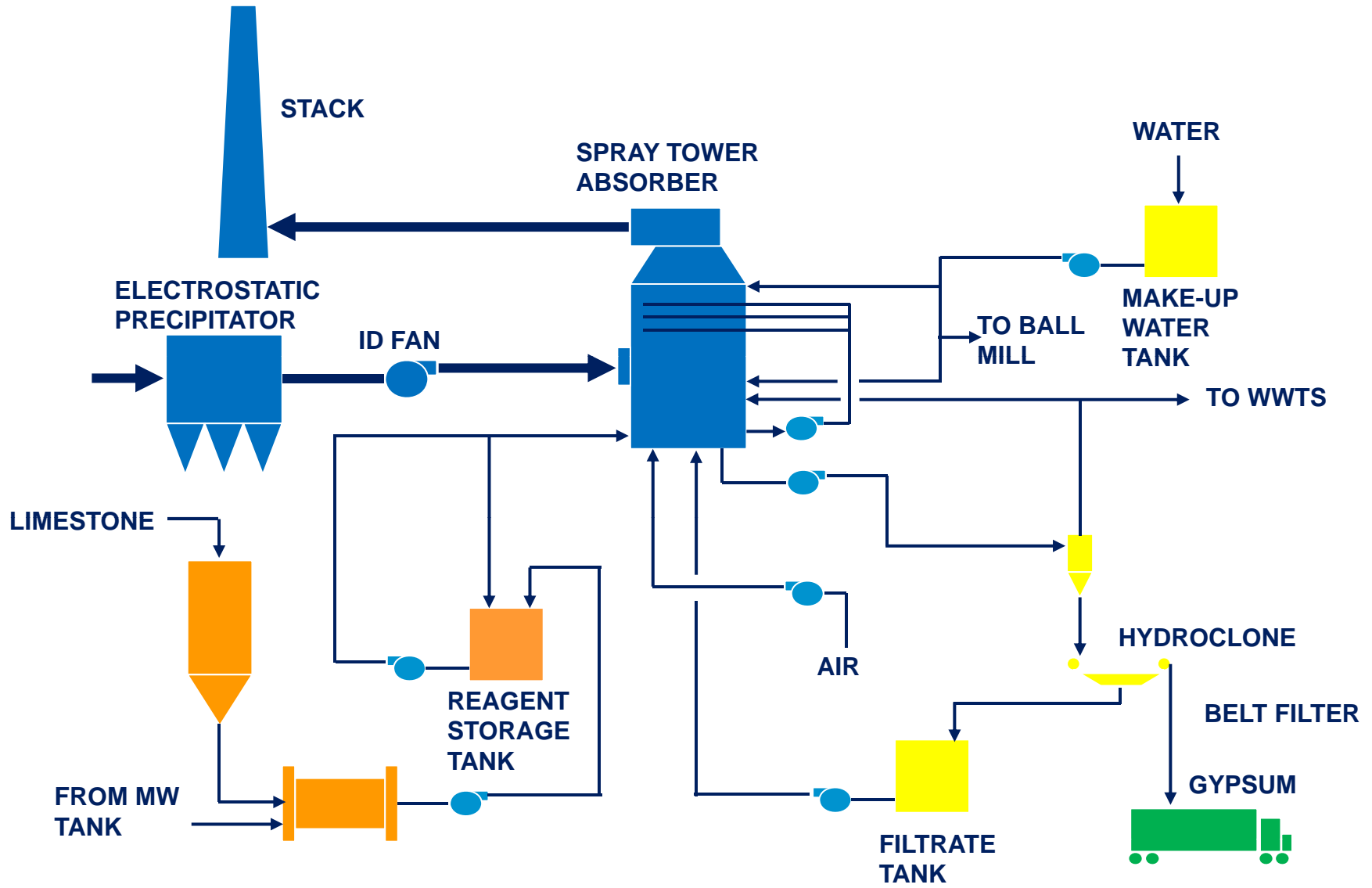


- ▶ A reagent (typically limestone slurry) is employed to remove sulfur dioxide from the flue gas:



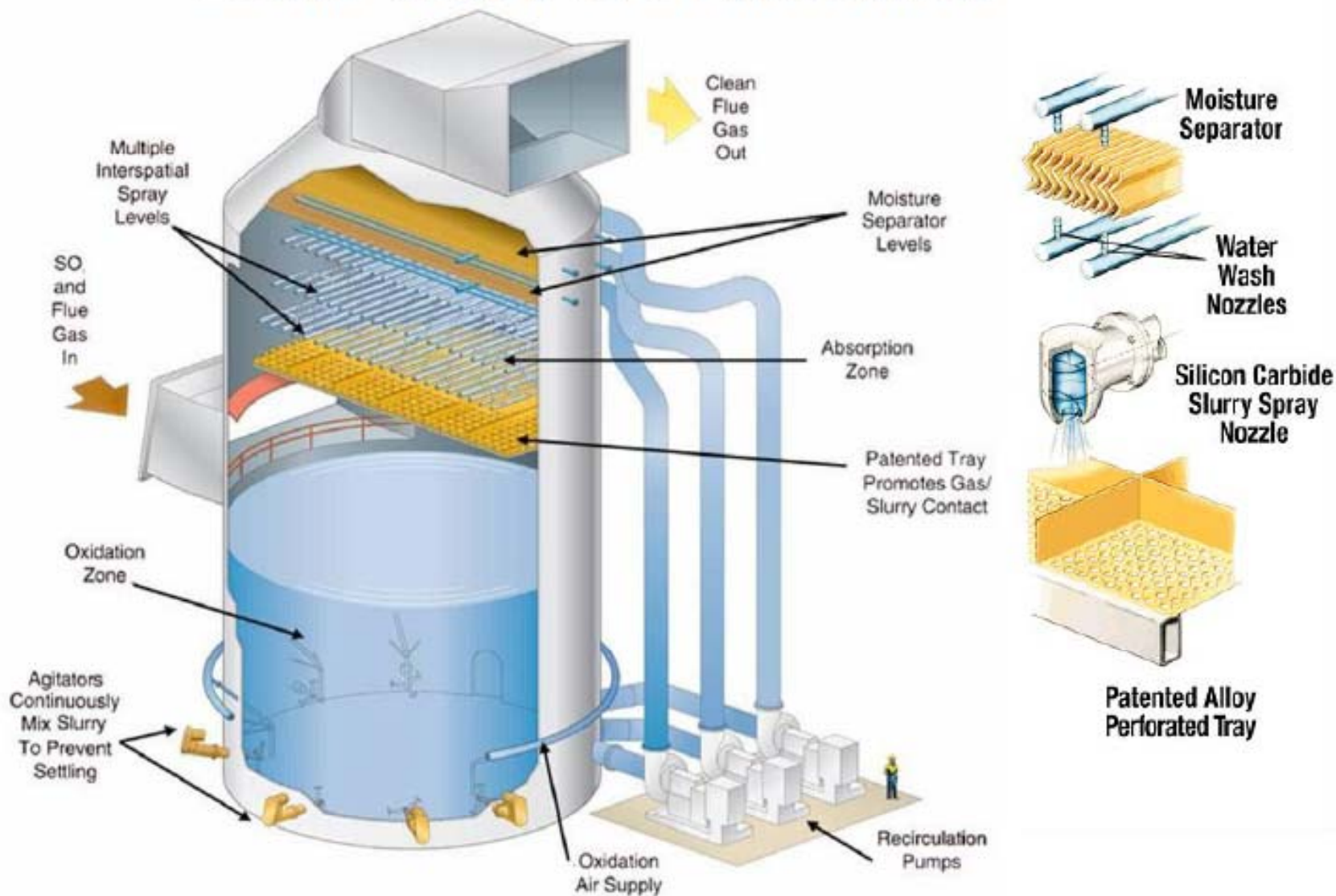
- ▶ An additional step, forced oxidation involving the injection of air into the FGD absorber, producing by-product, gypsum, (calcium sulfate) $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
- ▶ Removal efficiencies can be as high as 99%.

Wet Limestone FGD – Process Flow Diagram



Alstom

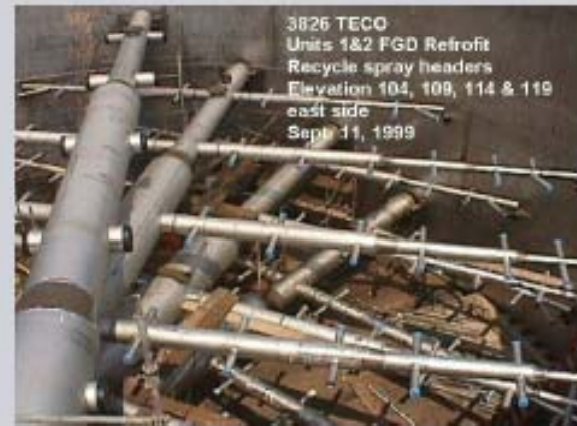
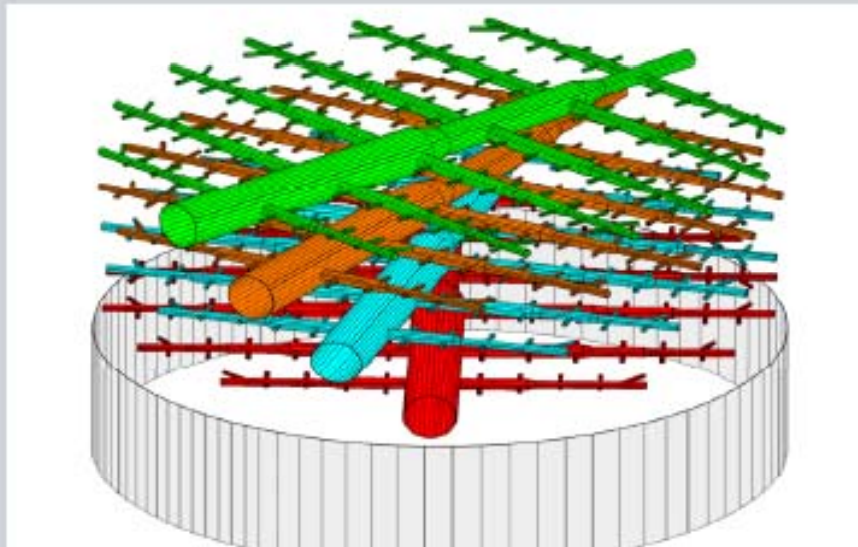
B&W Wet FGD Absorber



Wet Flue Gas Desulfurization (WFGD) Technology

Slurry Spray Header Placement

SIEMENS



Wet Flue Gas Desulfurization System - Example



Wet LSFO FGD - examples

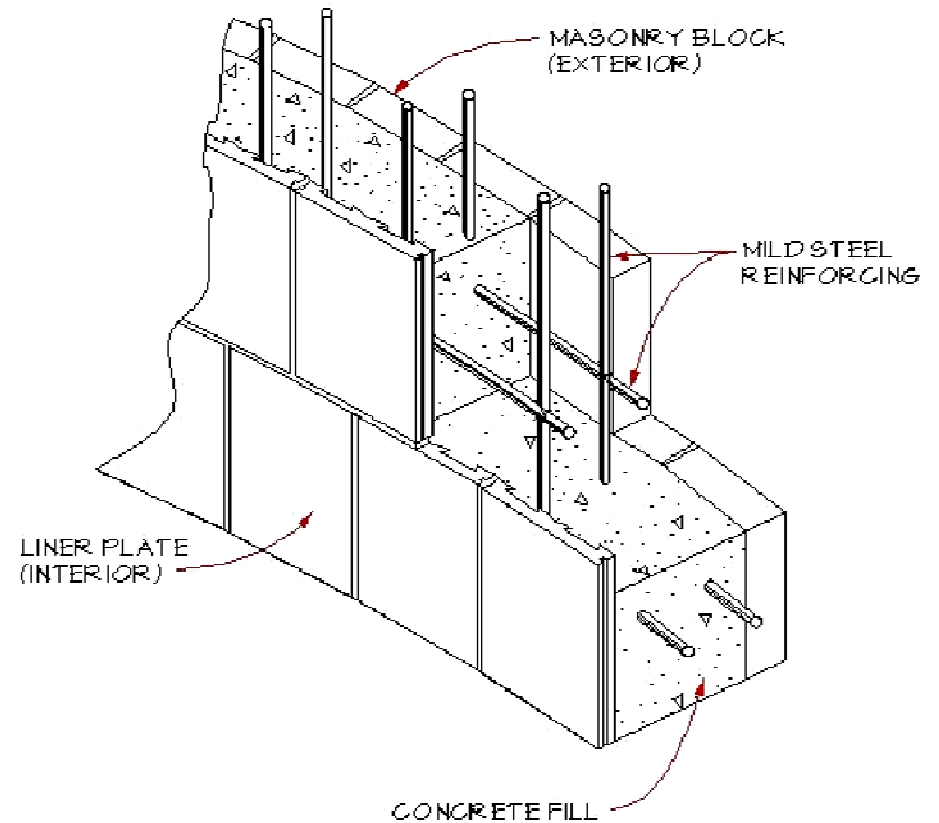
Safety, Quality, and Schedule with Modular Construction



Duct Installation



Stebbins - Absorber



Stebbins – Wet LSFO FGD Absorber

Wet FGD Gypsum Dewatering System - example



Wet LSFO FGD Gypsum Dewatering Filter

Upgrade of Existing FGD Systems

Brief List of Reasons Why Utilities May Want to Upgrade



- ▶ Increase SO₂ removal
- ▶ Increase amount of flue gas that is scrubbed
- ▶ Increase mercury removal (co-benefit Hg)
- ▶ Convert to higher sulfur fuel (coal, pet coke, oil)
- ▶ Convert to LSFO FGD (**produce wallboard- and/or cement-grade gypsum**)
- ▶ Test larger atomizer drives in existing SDA FGD
- ▶ Increase reliability of existing FGD system
- ▶ Repair severe corrosion of FGD system materials
- ▶ Other reasons for upgrading older FGD systems

FGD Upgrades – ALRD[®] Retrofit

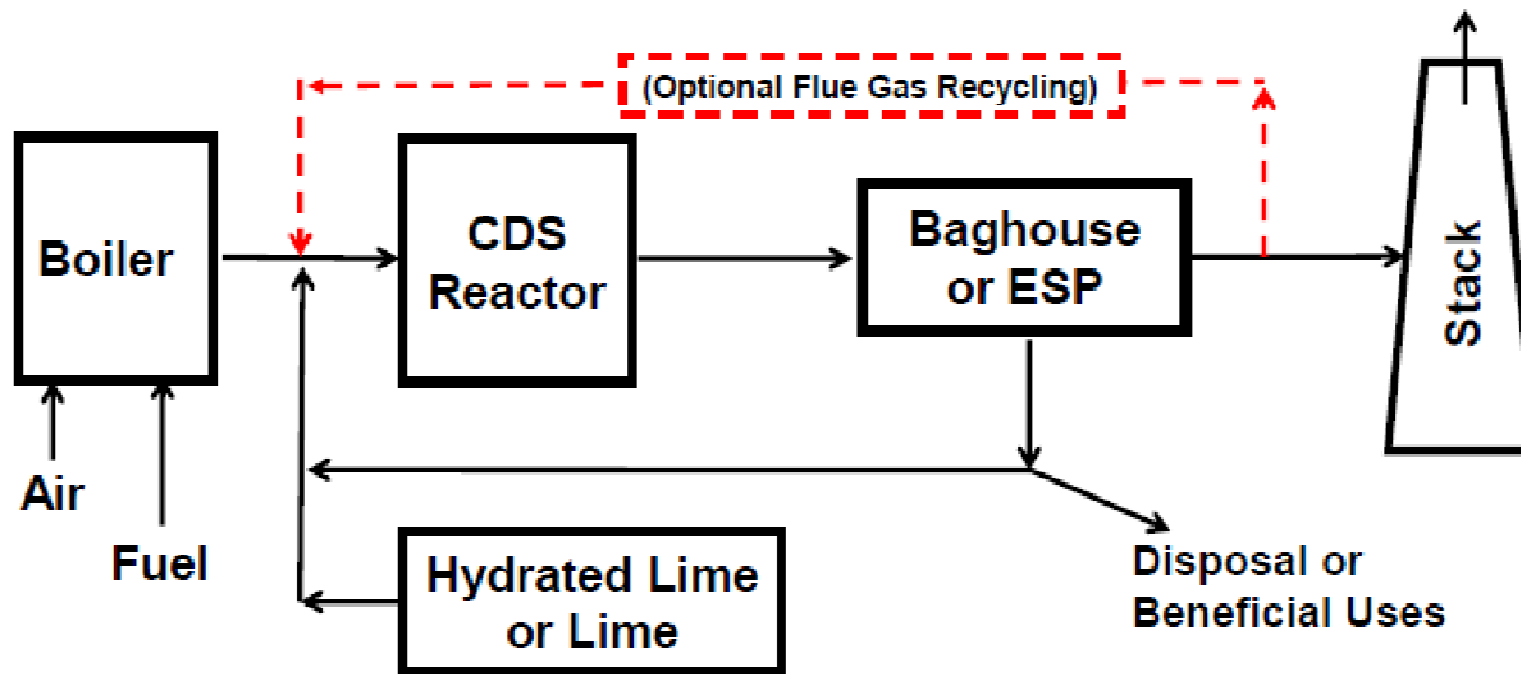
Absorber Liquid Redistribution Device (ALRD[®]) addresses sneakage of partially untreated flue gas due to poor liquid/gas contact, poor gas distribution and uneven spray density accounts for the majority of SO₂ emissions

Increased SO₂ removal

- Allows operation with higher sulfur coals
- Allows meeting new, more stringent permit emission levels
- Reduce power consumption (lower L/G)
- Removal of packing or trays (lower pressure drop)



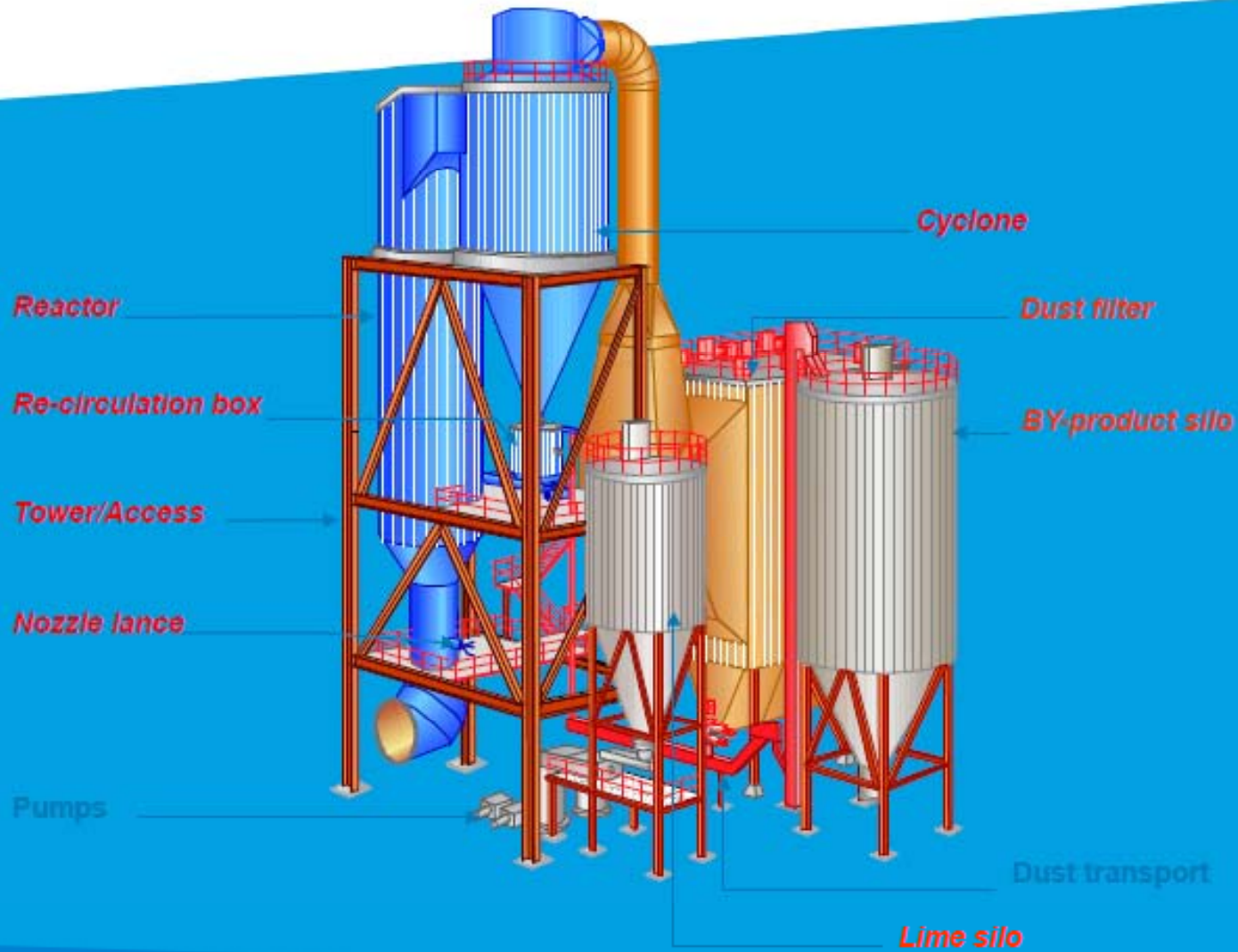
Generic Process Flow Diagram of a CDS System



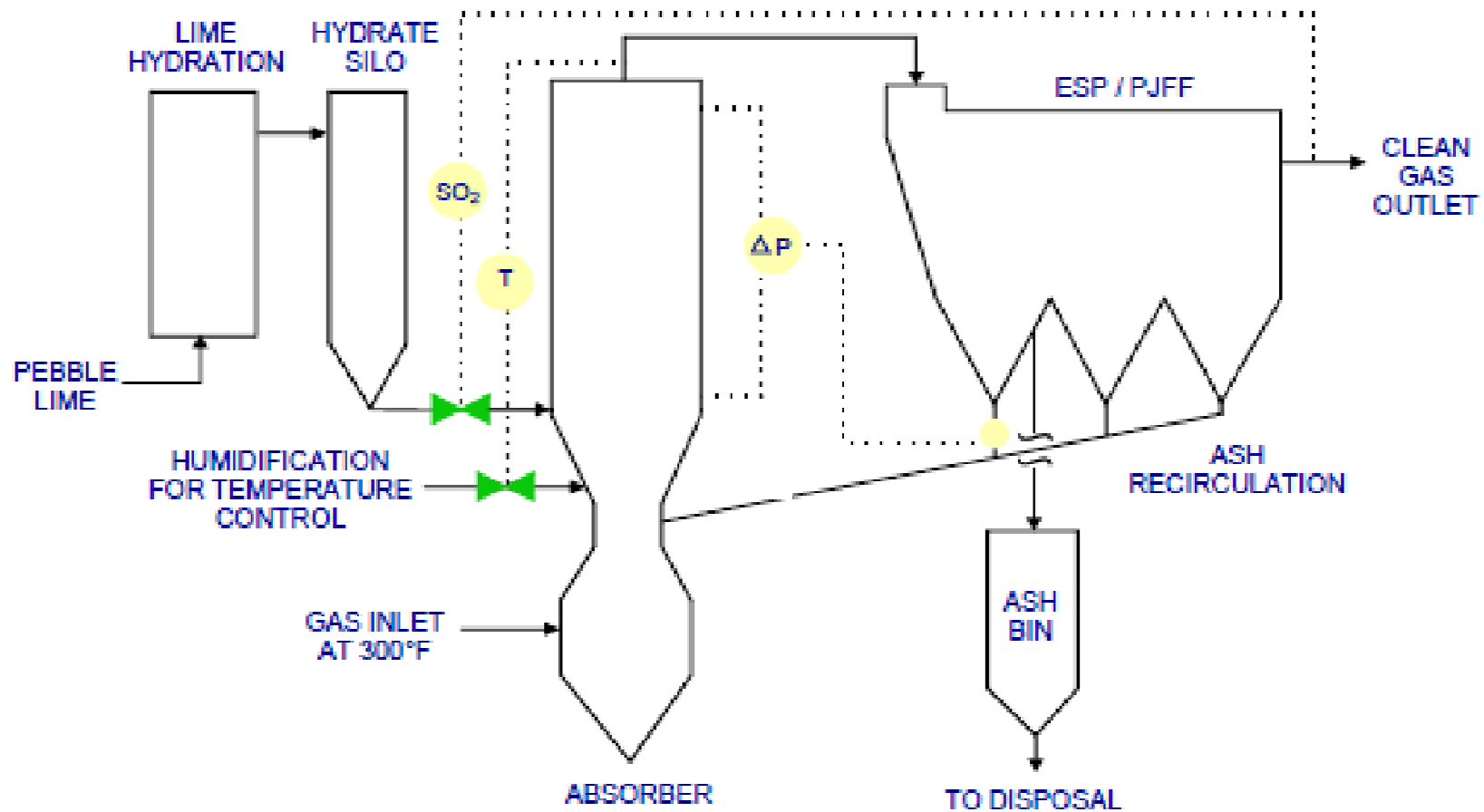
- **System Advantages:**
 - **Recirculation of ash provides high lime efficacy**
 - **No spray nozzles/atomizers and no circulation pumps keep capital and O&M costs low**

Gas Suspension Absorber

Typical layout

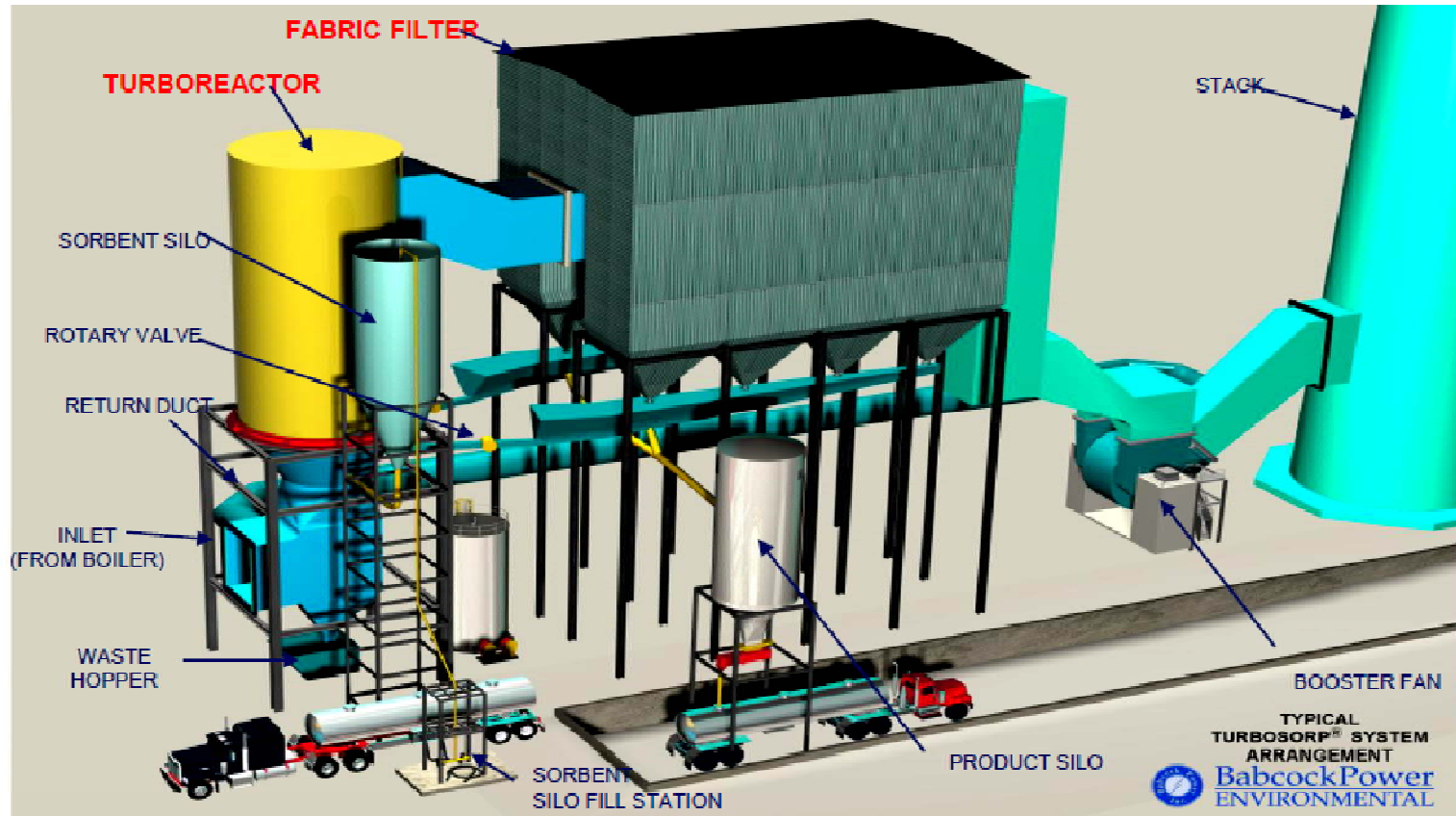


Allied Typical CFB Scrubber PFD





Turbosorp® Single Unit GA



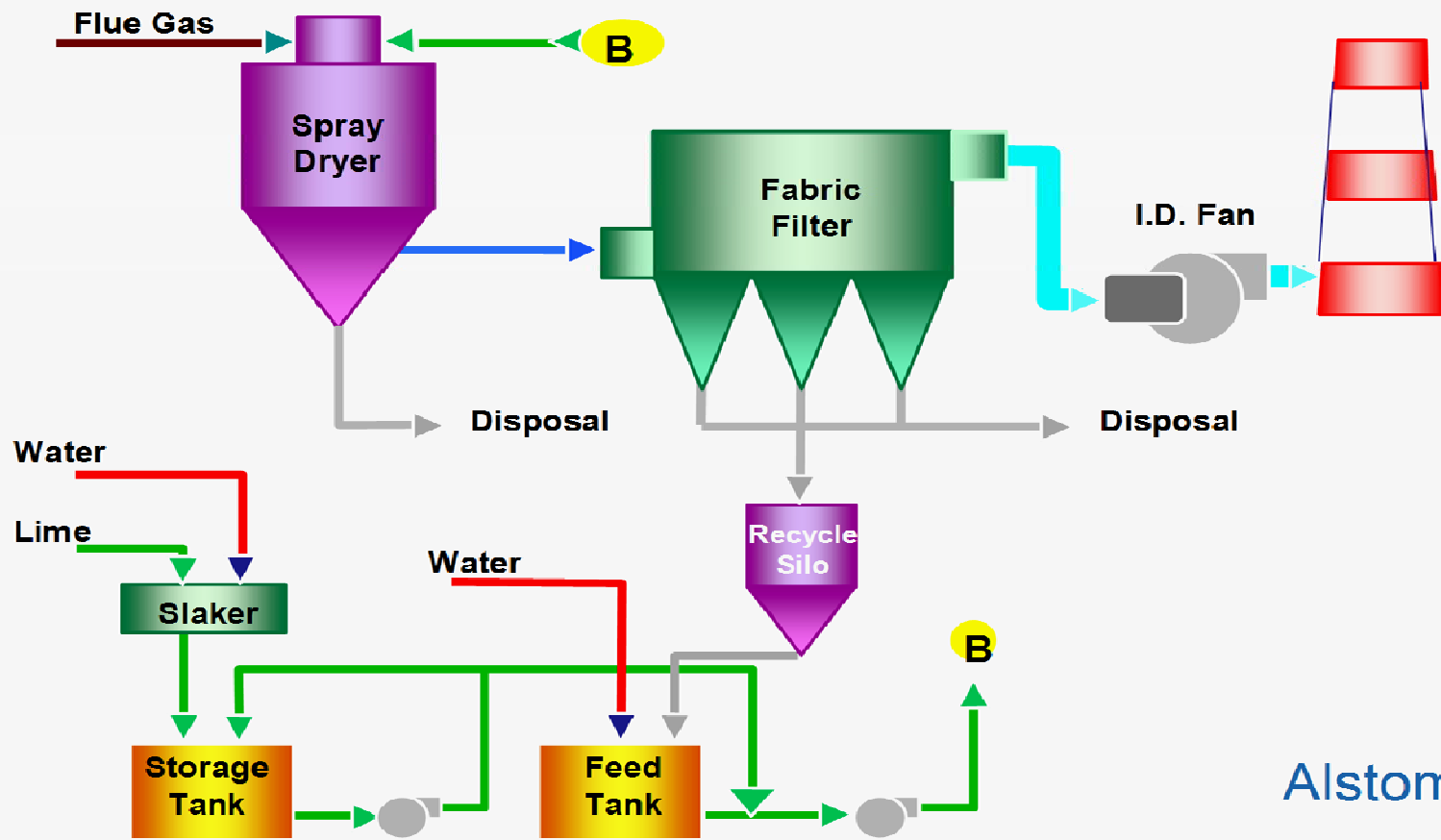
Circulating Dry Scrubber System - Example



CDS FGD with PJFF



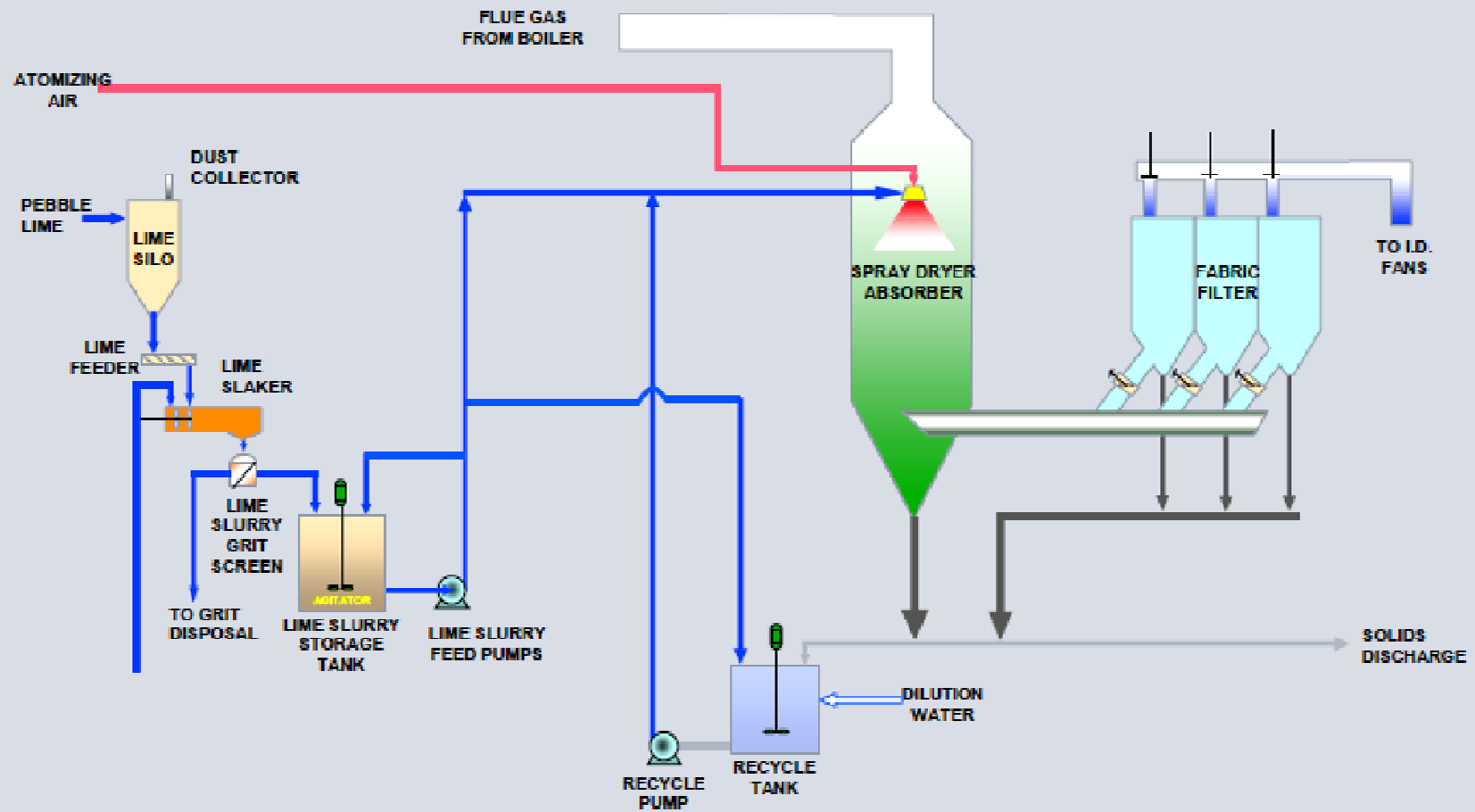
Dry FGD with Recycle



Alstom

Spray Dryer Absorber Technology

SIEMENS



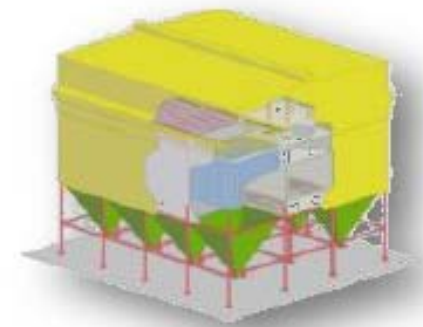
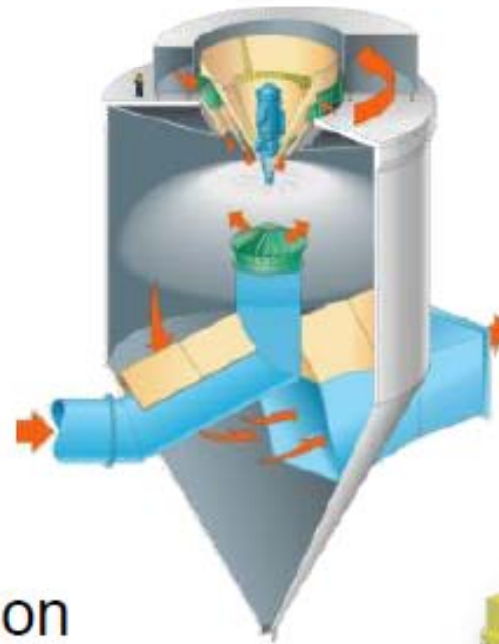
Characteristics of Dry FGD Systems

Typical Application

- ▶ < ~1.5% sulfur fuel
- ▶ Up to 97% removal

Process Advantages

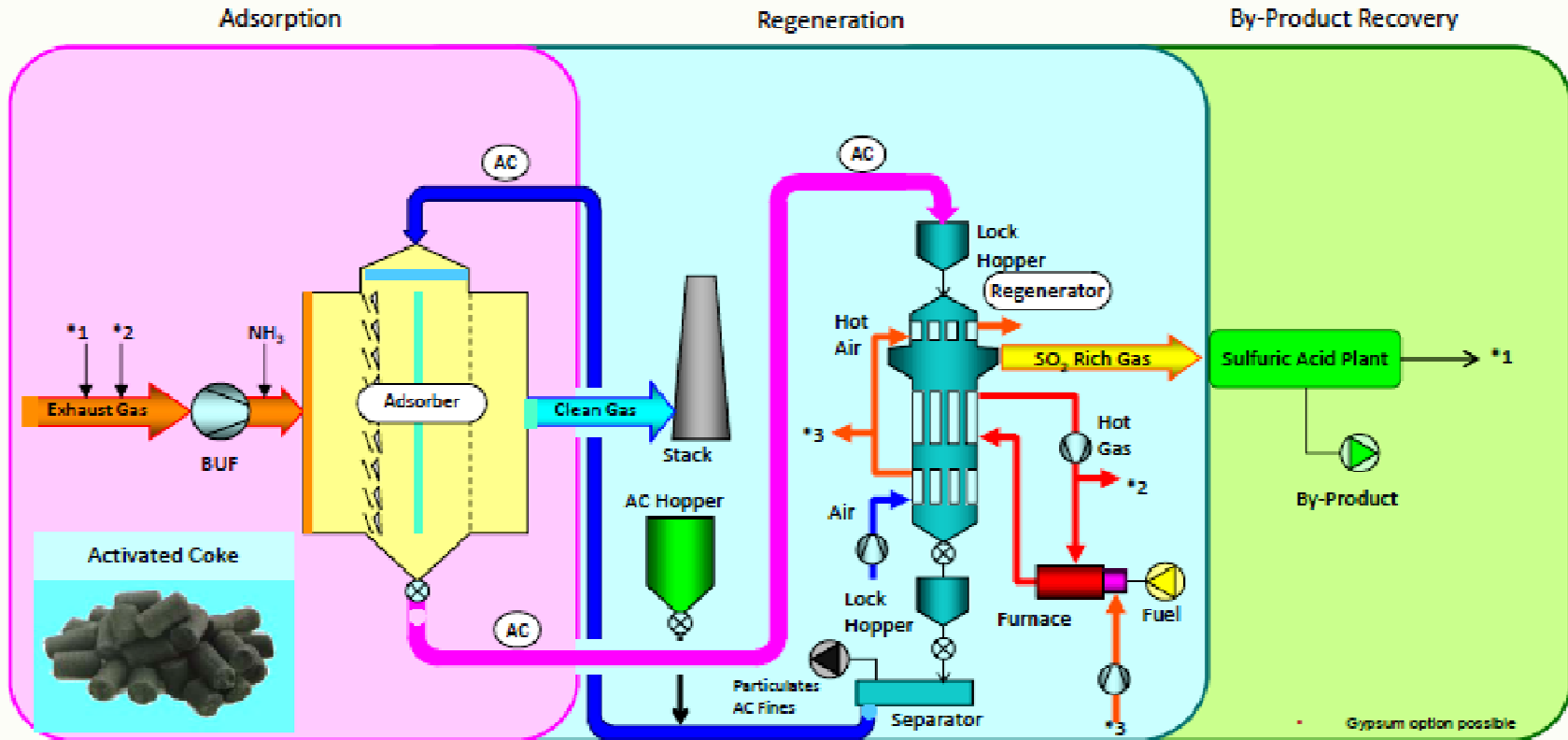
- ▶ Decreased material costs
- ▶ Decreased power consumption
- ▶ Decreased water consumption
- ▶ Process control simplicity



Re-Use of Dry Scrubber Material Byproduct Potential Concepts for Evaluation – examples



- ▶ Mine Reclamation
- ▶ Light Weight Aggregate Manufacture
- ▶ Processing of DSM in Ash Handling Process
- ▶ Process to Remove PAC from DSM
- ▶ Cement and Concrete Production
- ▶ Agricultural Fertilizer (if applicable)
- ▶ Use of Distributors and Brokers
- ▶ Civil and Structural Engineering Applications
- ▶ Other Methods for Re-Use



- Balance of plant systems not shown
 - Ammonia supply
 - Nitrogen

Hamon Group

Cooling Systems

Air Pollution Control

Process Heat Exchangers

Chimneys

HRS&G & Waste Heat Boilers



J-Power Isogo

The J-Power Isogo repowering project replaced 2x265 subcritical PC boilers with wet FGD, with 2x600MW ultrasupercritical boilers with SCR, ESP, and ReACT. The project site is 35 acres and Unit #1 was operational in 2002 before the original units were removed. Unit #2 started in 2009.

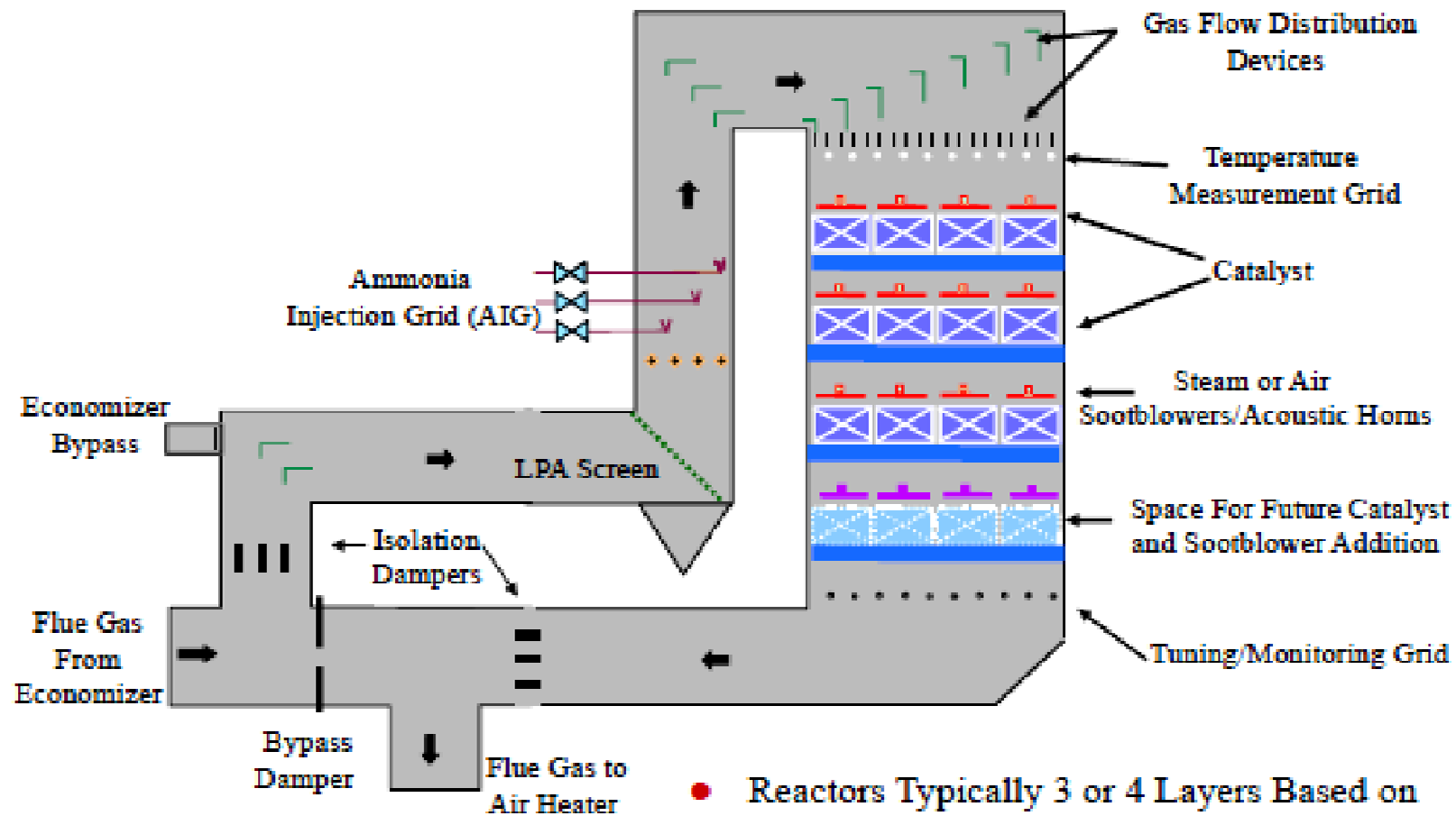


Integrated
solutions
for a clean
environment

Nitrogen Oxides (NO_x)



SCR System Reactor Arrangement (High Dust)



- Reactors Typically 3 or 4 Layers Based on Catalyst Deactivation Rate (Fuel Dependent)
- Need for Reactor and Economizer Bypass is a Project Specific Decision

SCR Chemistry for NO_x Reduction (example reactions)



- ▶ $4 \text{ NO} + 4 \text{ NH}_3 + \text{O}_2 \rightarrow 4 \text{ N}_2 + 6 \text{ H}_2\text{O}$
- ▶ $\text{NO} + \text{NO}_2 + 2 \text{ NH}_3 \rightarrow 2 \text{ N}_2 + 3 \text{ H}_2\text{O}$
- ▶ $6 \text{ NO}_2 + 8 \text{ NH}_3 \rightarrow 7 \text{ N}_2 + 12 \text{ H}_2\text{O}$
- ▶ $2 \text{ NO}_2 + 4 \text{ NH}_3 + \text{O}_2 \rightarrow 3 \text{ N}_2 + 6 \text{ H}_2\text{O}$

General System Design Parameters

Operating temperature

- Min ~600 °F
- Max 780 °F

Velocity in SCR fluework

- 50 to 60 ft/sec

Velocity through reactor

- < 16 ft/sec

NO_x performance (coal)

- Greater than 90% reduction
or ~0.03 lbs/MBtu NO_x

Ammonia slip (coal)

- 2 - 5 ppm (dependent on fuel)

SO₂ to SO₃ Conversion

- ≥ 0.25% per layer

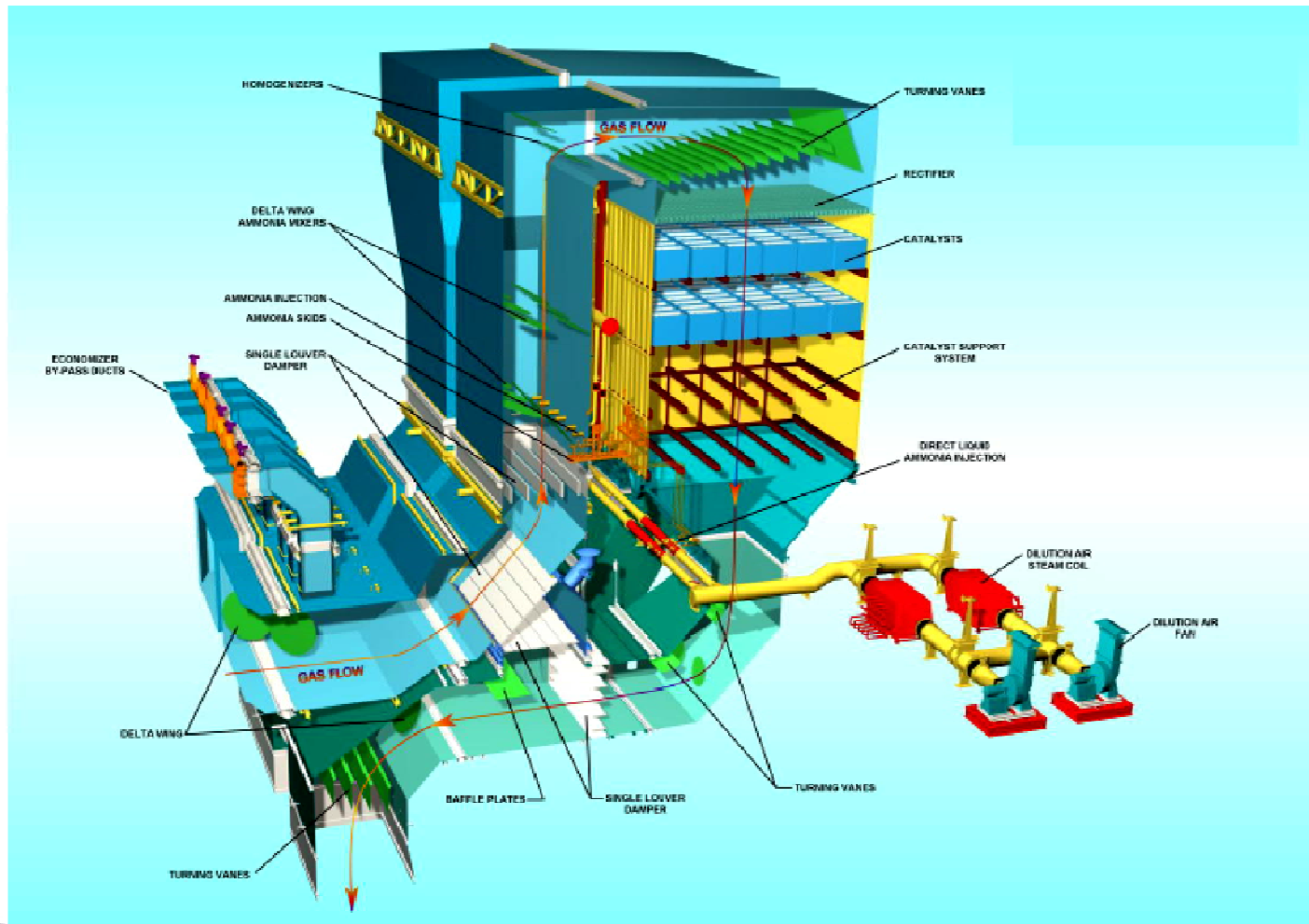
Pressure drop

- As necessary for system
equipment





SCR Reactor Configuration



Selective Catalytic Reduction System Nitrogen Oxides (NOx) Removal - Examples

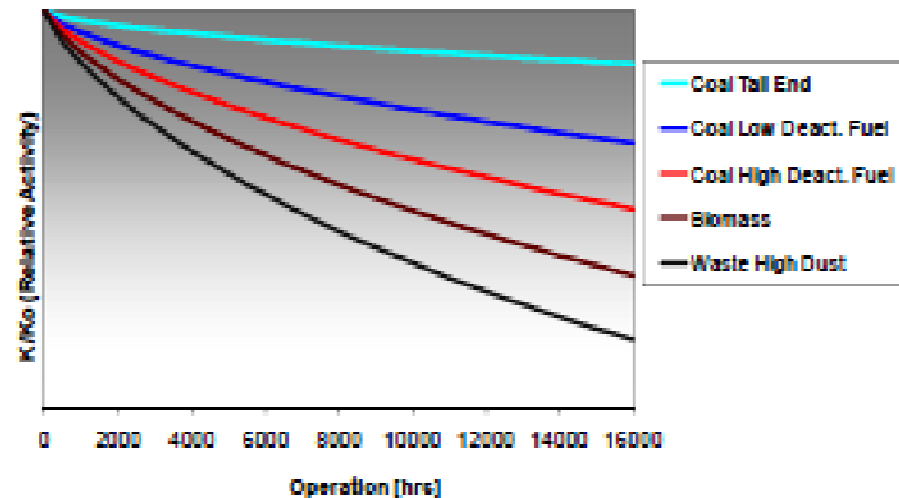


SCR Systems - examples

Catalyst Deactivation Mechanisms

- Catalyst Poisons:

- Arsenic
- Potassium
- Phosphorus
- Sodium
- Cadmium
- Lead
- Copper
- Other Elements



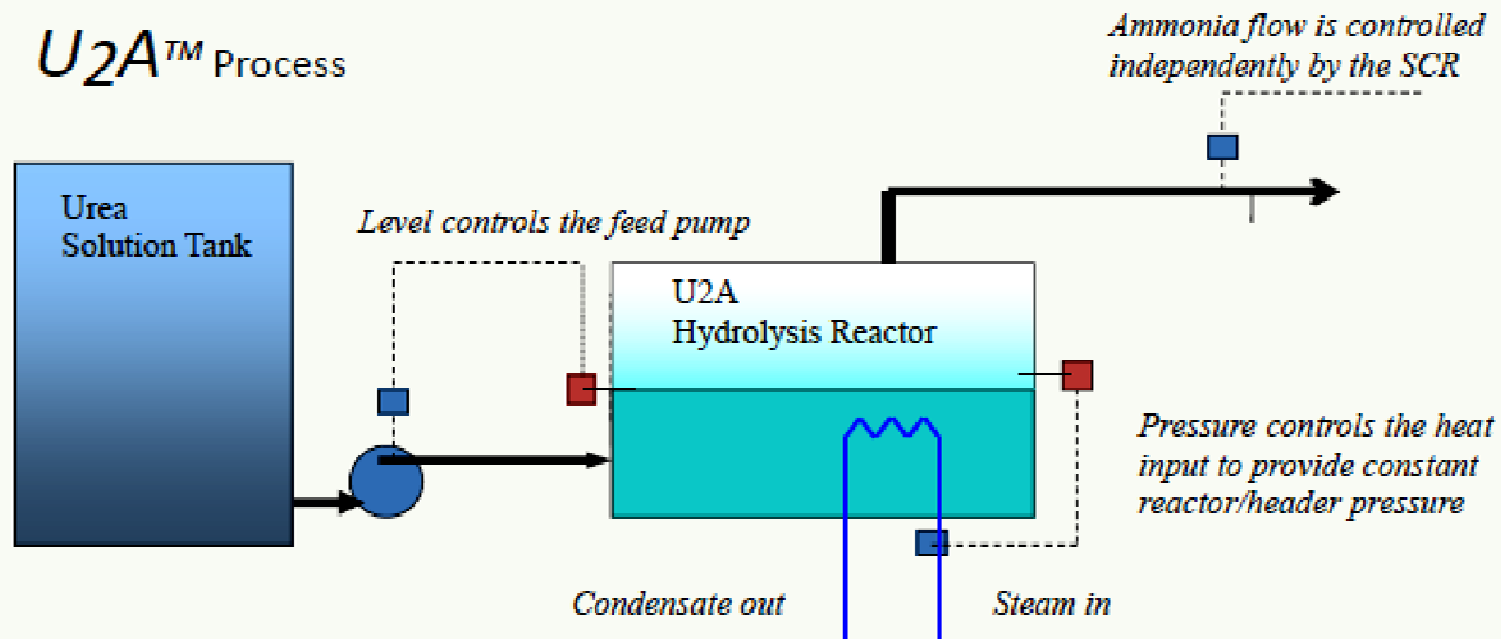
- Fouling by Solid Compounds

- Gypsum (Calcium Sulfate) and Other Solid Compound Deposition
- Ammonium Bisulfate (Avoided by Keeping Above Permissive Temperatures)

- Deactivation Occurs During...

- Normal SCR Operation
- Startups and Shutdowns as Unit Goes Through Acid Dew Point

U₂A™ Process

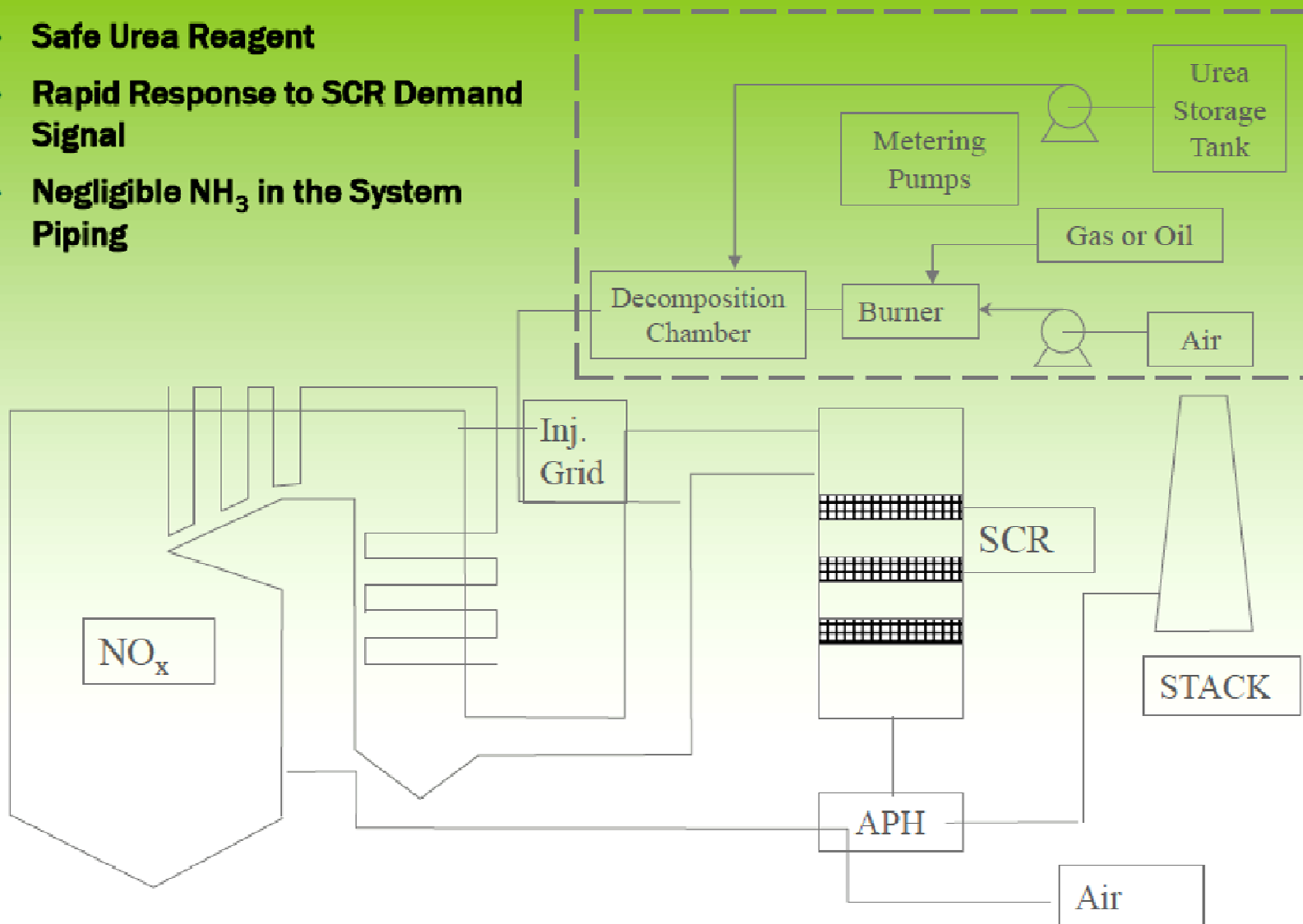


800 lb/hr Hydrolyzer Skid



ULTRA™ Technology

- Safe Urea Reagent
- Rapid Response to SCR Demand Signal
- Negligible NH_3 in the System Piping



- ▶ Urea Conversion Processes Improvements
- ▶ Mercury Oxidation - SCR Catalyst
- ▶ Reduced SO₂ Oxidation – SCR Catalyst
- ▶ Improved Mixing of Flue Gas & Ammonia (CFD, mixing devices, etc.)
- ▶ Reduced Ammonia Slip (ash sales issue, and FGD CPS issue)
- ▶ Pre-removal of Ash Before SCR (pop-corn ash)
- ▶ SCR Catalyst Regeneration Techniques
- ▶ Other SCR Advances

- ▶ **Overall Removal Chemistry** – Urea (H_2NCONH_2) decomposes to ammonia (NH_3) which reacts with Nitrogen Oxides (NO_x).
- ▶ **Overall Reaction Products** – Main reaction byproducts include nitrogen (N_2), water (H_2O), carbon dioxide (CO_2), and small amount of ammonia (NH_3) slip.
- ▶ **Key Process Issues** – Inject urea at proper temperature window within the furnace, with proper penetration and mixing, plus proper residence time to allow the chemistry to reduce the required amount of flue gas NO_x while minimizing the ammonia slip (NH_3).

SNCR Test Equipment - example



NO_x reduction is demonstrated before proceeding with a permanent system design.

SNCR Permanent Equipment - examples



SNCR Permanent System



**Boiler Tube Insert for
SNCR System**

**Co-firing Fuels
Impacts on AQCS**



Co-firing Fuels – Impacts on AQCS



- ▶ Co-firing solid biomass with coal (wood, RDF)
- ▶ Co-firing liquid bio-mass with oil (blend palm oil, bio-diesel)
- ▶ Co-firing gaseous bio-mass with NG (landfill gas)
- ▶ Co-firing natural gas with coal

Design and O&M - Co-firing Fuels Air Quality Control System



- ▶ High Moisture Content of Flue Gas (maintain f.g. temp)
 - Avoid Corrosion of PM Collector (ESP, PJFF)
 - Avoid Pluggage of PJFF Bags (damp solids, avoid ABS)
 - Select proper PJFF bags and cages
- ▶ Flyash of Flue Gas (ash content and composition varies)
 - Avoid hot spots/fires (combustor & cyclone, protect hoppers, ESP, PJFF)
 - Accommodate ash handling erosion (e.g., ash SiO_2 , Al_2O_3)
 - Potential fine particles (fuel brackish water → aerosols → WESP)
 - Boiler Slagging/Fouling (animal activity biomass → NaCl)
 - Avoid ABS (SNCR → NH_3 slip → NH_4HSO_4)
- ▶ Trace Elements of Flue Gas (protect downstream AQCS)
 - Impact on SCR Catalyst (Ca, As, etc.) (clean side SCR)

Design and O&M - Co-firing Fuels Air Quality Control System (con't)



- ▶ Acid Gas in Flue Gas (protect downstream AQCS)
 - Remove HCl/SO₂ as required to protect ductwork, ESP, PJFF, etc.
 - FGD or DSI (co-firing coal with bio-mass or natural gas)
- ▶ NOx in Flue Gas (nitrogen content varies)
 - Solid Biomass N → NOx (SNCR vs. SCR)
 - Liquid Biomass N → NOx (biofuel blending with fuel oils)
 - Select Proper SCR Catalyst (temp control – split economizer/APH)
 - Minimize SNCR ammonia slip
- ▶ CO, VOC, and other organics in Flue Gas
 - Combustion Optimization (oxidation catalyst or thermal oxidizer, if required)



Summary



- In addressing the Regulatory Environment, Utilities may evaluate a range of options.
- One of several options is to evaluate retrofit air quality control systems (AQCS).
- Wide range of AQCS technologies are available.
- Selection of AQCS type is based on plant specific economic and technical considerations.
- Operation and Maintenance issues should be addressed in selection of the AQCS.



Open Discussion





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