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Wet & Dry Scrubbers

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Dry FGD/DSI Topics

DRY FGD

Technology Variations

Technology Description

- Reagent Handling and Preparation
- Absorber System
- Baghouse System
- Waste Recycle System
- Flue Gas System

Dry FGD Technology Suppliers

Dry FGD/DSI Topics

DRY SORBENT INJECTION (DSI)

DSI vs. Other FGD Options

Types of Sorbent

Trona vs. SBC

Current Industry Trends

DRY FGD
Technology Variations

Dry Scrubbers

- Spray Dryer Absorber (SDA)
  - Rotary Atomizer
  - Dual-Fluid Nozzle
- Circulating Dry Scrubber (CDS)
  - Fluidized Bed FGD
  - NIDS

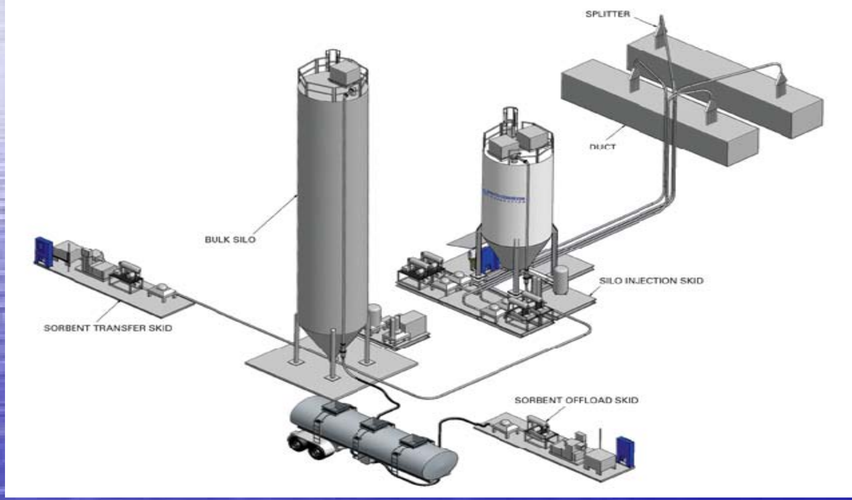
Dry Sorbent Injection (DSI)

Dry FGD – Rotary Atomizer

Dry FGD – Dual Fluid Nozzle

Dry FGD – Circulating Dry Scrubber

Dry Sorbent Injection (DSI)



Dry FGD

Spray Dry Flue Gas Desulphurization (FGD)

Circulating Dry Scrubber (CDS) or Circulating Fluidized Bed (CFB) Scrubber

NIDS

- A subset of CDS

Dry Alkali Injection for SO_2 control

Commonality Between Dry Systems (SDA and CDS)

- All Systems Require a Particulate Collection Device downstream of the absorber – preferably a baghouse but could use an ESP
- Both use a lime derivative – $Ca(OH)_2$ as the reagent
  - Spray Dryer uses it wet in a slurry
  - CDS uses semi-dry hydrate & adds water separately
- Both have limited module sizes:
  - SDA = 450 MW
  - CDS = 400 MW operating, up to 490MW
  - NID = 75 MW/module, multiple modules compose a system

Commonality Between Dry Systems

- Because both systems stay at least 30°F above the dew point, both use carbon steel as the primary material of construction.
- Because both systems stay at least 30°F above the dew point, the existing chimney can be re-used in a retrofit.
- Both systems recycle large amounts of baghouse catch back to the absorber to improve lime usage.
- Both produce a sulfite-sulfate mixed material that must be landfilled.
  - Can be used in low grade concrete aggregate when mixed with fly ash.

Dry FGD Chemistry

Coal Sulfur forms gaseous SO_2 & SO_3

Lime is received as CaO (pebble lime)
(3/4" x 0" for Dry FGD or CDS, 1/8" x 0" for NID)

Lime is slaked/hydrated as follows:

$CaO + H_2O \rightarrow Ca(OH)_2$

In the absorber, SO_2 is captured as:

$Ca(OH)_2 + SO_2 \rightarrow CaSO_3{\bullet}½H2O + 1/2\ H_2O$ (70-75%)

$Ca(OH)_2 + SO_2 + H_2O + 1/2O_2 \rightarrow CaSO_4{\bullet}2H2O$ (25-30%)

In a CDS absorber, CO_2 is captured as:

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

Stoichiometric ratio

- Stoichiometric Ratio often referred to as the Ca/S ratio
  - Actual moles of calcium/theoretical amount of calcium required for the moles of SO_2 collected
- For wet FGD it is expressed as a ratio to the SO_2 collected.
  - Typical values would be 1.03 to 1.05
- Dry system suppliers express their usage on the basis of the inlet SO_2 not the SO_2 collected like the wet systems.
  - Typical values would be 1.1 to 1.4 for PRB Coal for 95% Efficiency

Spray Droplet Chemistry

- Slurry droplet drying time is a function of the flue gas temperature at the SDA inlet
  - Higher the temperature, lower the residence time to dry the droplet
  - Typically 1-4 seconds is needed to dry the largest droplet

- Drying time is also a function of chlorides and recycle amount
  - Higher the $CaCl_2$, higher the residence time needed to dry the slurry droplet which can increase the amount of SO_2 capture
  - The lower the amount of fly ash in the recycle, the higher the residence time needed to dry a slurry droplet

Spray Dryer Absorber

Dual-Fluid Nozzles Versus Rotary Atomization Spray Dryers

- Footprint Is Smaller For Dual-Fluid Spray Dryer Than For Rotary Atomizer Spray Dryer
- Removal of One Dual-Fluid Nozzle (Out of 40) For Maintenance Has Less Of An Effect On Emissions Than One Rotary Atomizer (Out Of 2 [B&W] or 6 [Alstom])
- Spare Atomizer Costs –
  - B&W - $675,000 (1 atomizer per vessel)
  - Alstom - $250,000 (3 atomizers per vessel)
  - Siemens - $18,000 (20 nozzles per vessel)
- Maintenance Times –
  - Dual-fluid Nozzles - ~12 – 15 man-hours/week
  - Rotary Atomizers - ~20 – 30 man-hours/week

Dual-Fluid Nozzles Versus Rotary Atomization Spray Dryers

- Costs Between Dual-Fluid & Rotary Atomizer FGD Systems About Equal
- Energy Consumption Between The Two Technologies Is About The Same
- More Rotary Atomizer FGD Systems In Service Than Dual-Fluid Nozzles

Rotary Atomizer

For utility sized systems many atomizers are mechanical, rotary atomizers

Slurry is fed into a disc nozzle rotating at a high rate of speed

This spins fine droplets of slurry out into the gas stream – where they dry and are captured in the baghouse

Rotary Atomizer

Typical Rotary Atomizer (1-3 Per Spray Dryer)

Dual Fluid Nozzle

Certain Manufacturers use dual fluid nozzles as an alternative to the Rotary Atomizer in SDA

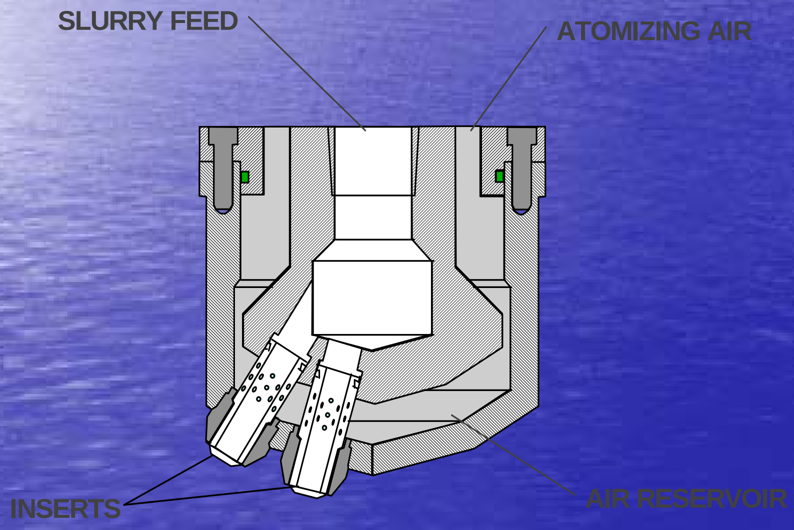
In the dual fluid nozzle lime slurry is atomized by a high pressure second fluid – predominantly compressed air to produce the fine spray needed

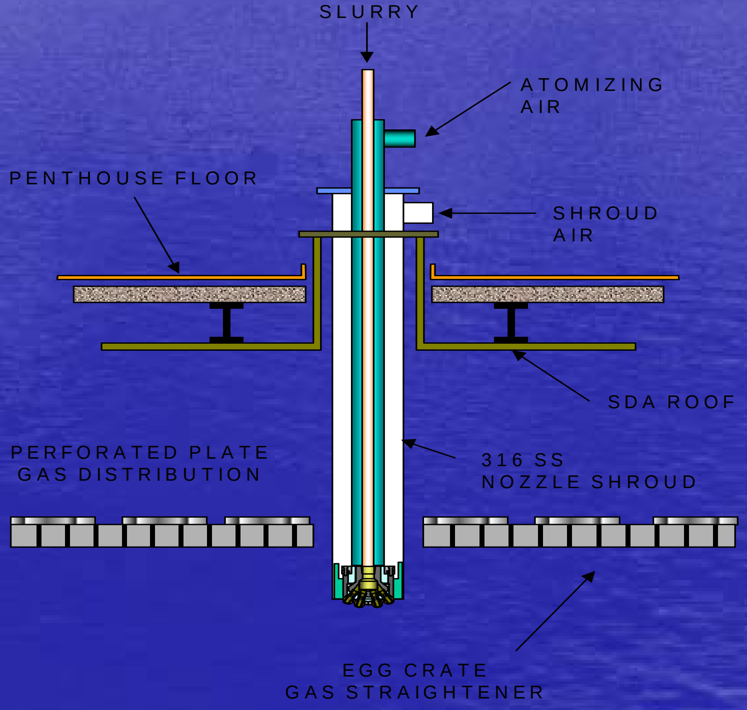
Dual fluid nozzles do not have high speed rotating parts like the Rotary atomizer

16-20 per absorber

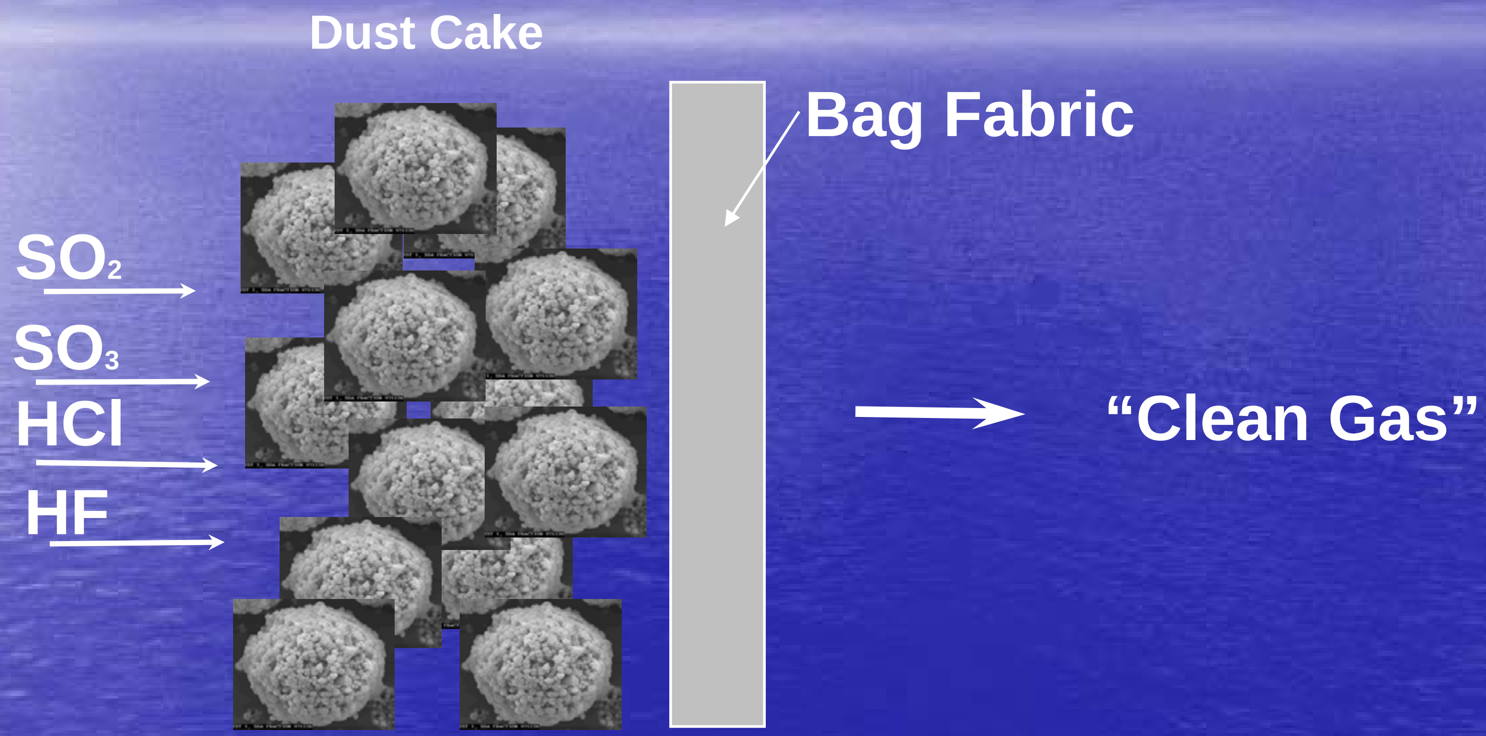
Our patented two fluid slurry nozzle

Typical Dual Fluid Nozzle (16-20 Per Spray Dryer)





SO_2 Absorption Continues in Baghouse



Baghouse contributes 10 to 20% of the total SO_2 removal – design SDA and FF as a system

Dry FGD Subsystems

- Reagent Handling and Preparation
- Absorber System
- Baghouse System
- Waste Recycle and Storage System
- Flue Gas System

Reagent Handling and Preparation

Reagent Handling and Preparation System

- Lime Handling and Storage
  - Pneumatic Conveying to long term silos
  - 30 days capacity factor storage
  - Pneumatic conveying to Preparation system
- Lime Slurry Preparation system
  - 24 hours day bin
  - 2 x 100% slakers
  - 20% slurry
  - 8-16 hours slurry storage
  - slurry piping (loop to absorbers)

Lime Handling and Storage

Lime Unloading System

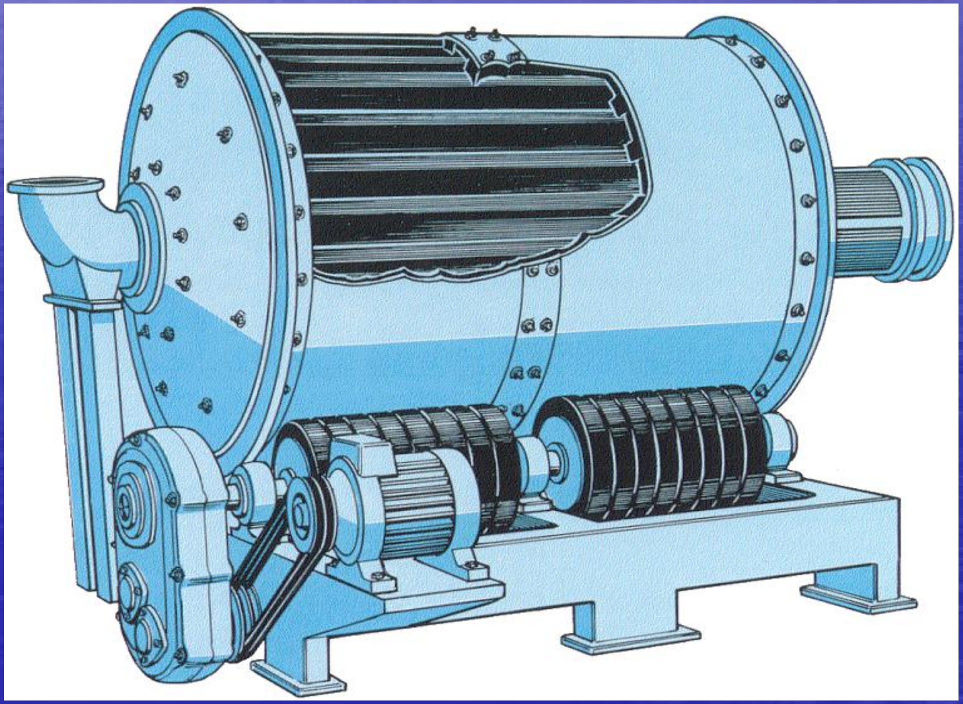
Lime Slaking / Hydration Process:

- Exothermic Hydration Process
- Operating Temperature
- Quality of Lime
  - MgO, $CaCO_3$, "Grits"
- Quality of Water ($SO_4^{=}$, $SO_3^{=}$)

$$CaO + H_2O \rightarrow Ca(OH)_2$$

Ball Mill Slakers

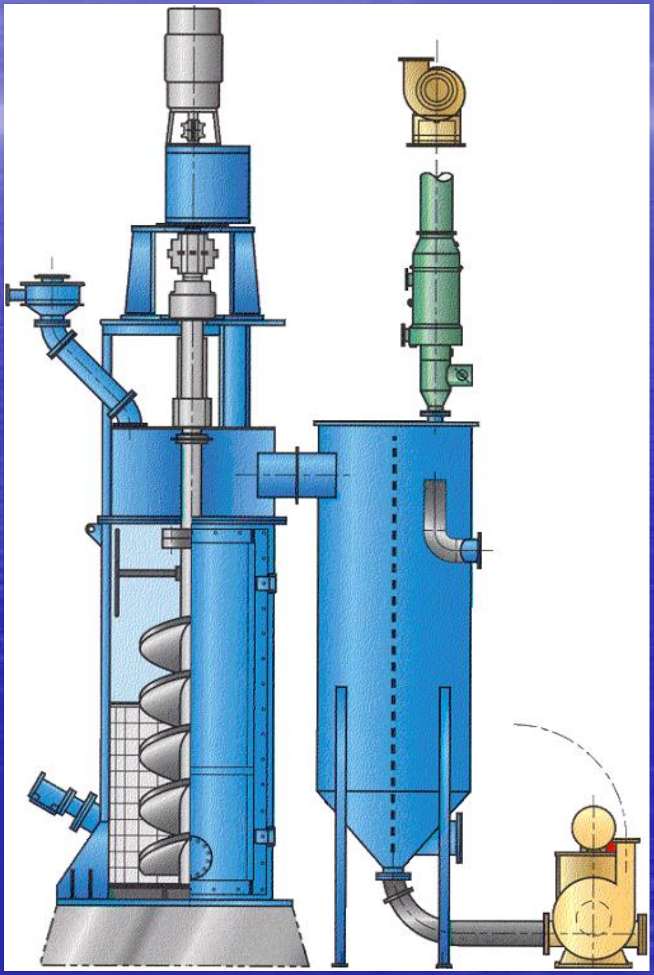
- Conventional Ball Mill Slaker
- Rotating cylinder
- Steel balls create the grinding action
- Ball mills grind the grit



Ball Mill Slaker

VertiMill Slakers

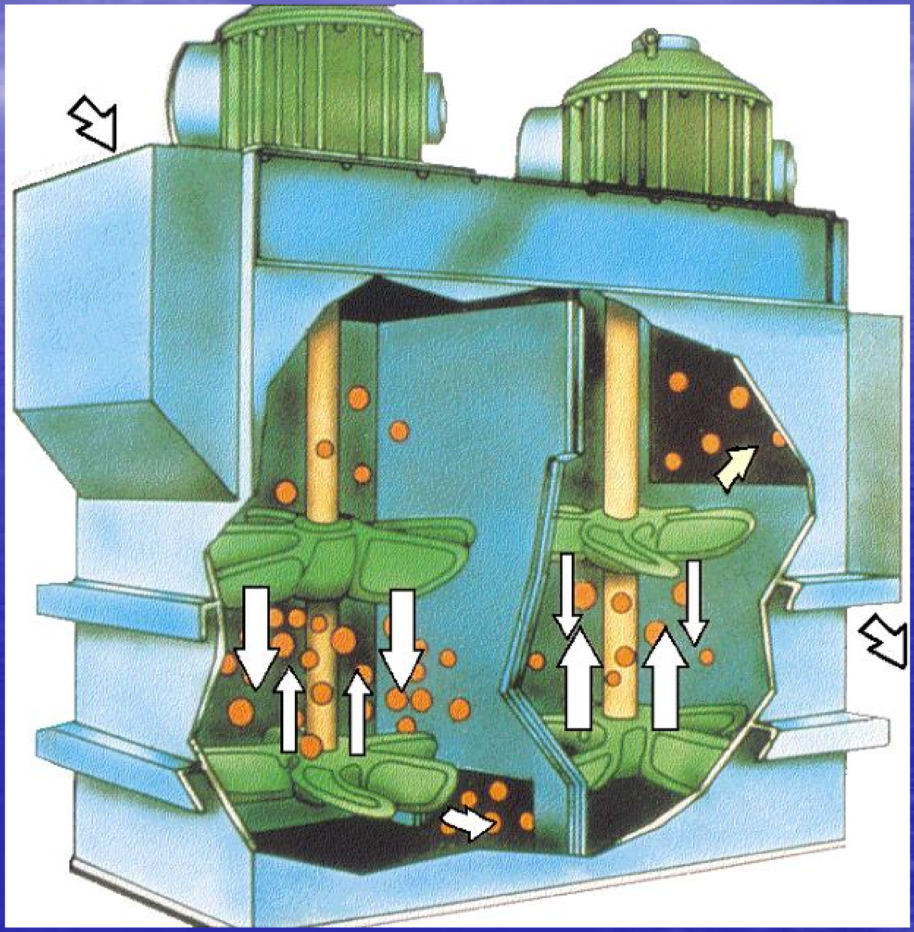
- Steel balls create the grinding action
- Finer Particle Size
- Less Power Than a Ball Mill Slaker



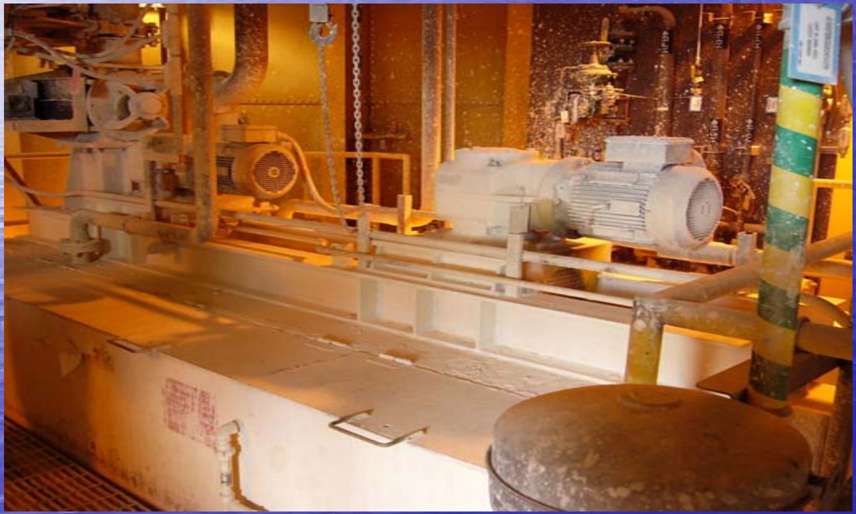
Vertimill Slaker

Detention Slakers

- Violent Agitation – No steel balls
- Opposed Pumping Turbines
- Particle to Particle Contact = Attrition
- Grit is removed by screens that follow the slakers. Also included in recycle trains



Detention Slakers Require Grit Removal



CDS Systems Use Hydrators Instead of Slakers

- Same chemical reaction in a hydrator as a slaker
  - $CaO + H_2O \rightarrow Ca(OH)_2$
- 500 Btu's of heat released per pound of lime slaked (278 kcal/kg)
- Only enough water used to hydrate the lime
- More difficult to operate than a slaker

Absorber System

- Minimum 10 Second Residence time
- Carbon Steel
- Atomizers
- Slurry mix tank

Spray Dryer

- Spray Dryer introduces a lime slurry into the hot flue gas by means of an atomizer
  - For utility sized systems atomizers are either rotary atomizers, or dual-fluid nozzles
  - With a Rotary Atomizer the slurry is fed into a disc rotating at a high rate of speed (~10,000 RPM).
  - With a Dual-fluid Nozzle compressed air mixes with the slurry at the nozzle tip
- Droplets are dispersed into the flue gas stream, reacts with the SO_2, and are dried into fine powder

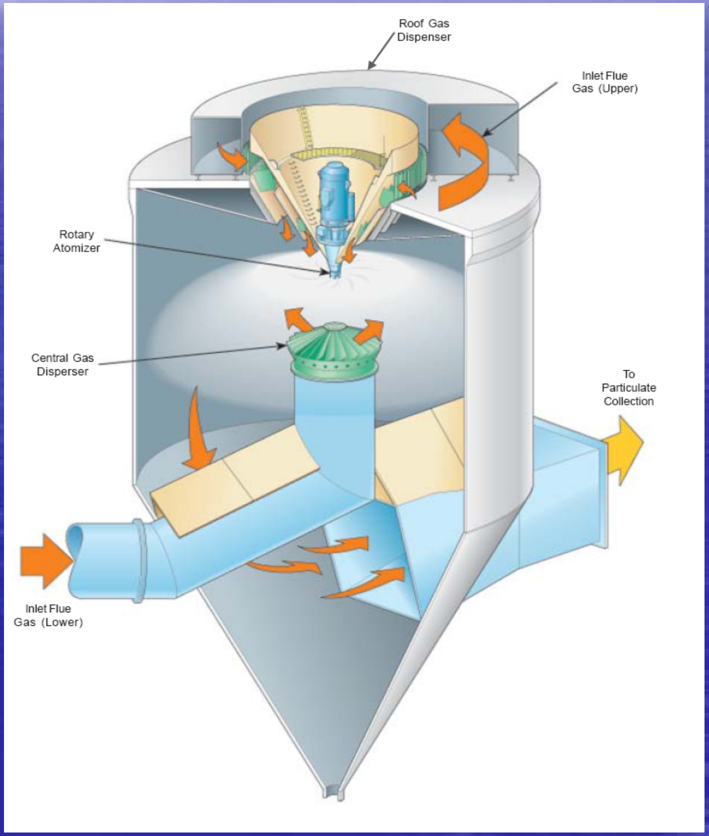
Spray Dry Absorber

Hot flue gases are often split to aid in drying the slurry

Spray dryers are generally limited to low to medium sulfur fuels by the amount of water in slurry

Exit temperatures must stay above the adiabatic saturation temperature to ensure complete drying of droplets

Temperature above saturation defined as “Approach to Saturation”



B&W

Rotary Atomizer

- Rotary Atomizer shows dispersion of slurry from disk
- Atomizers are supplied with quick disconnects – as they are changed while the Unit is on-line
  - B&W design uses one atomizer in an SDA vessel
  - Alstom design use several atomizers in a single vessel

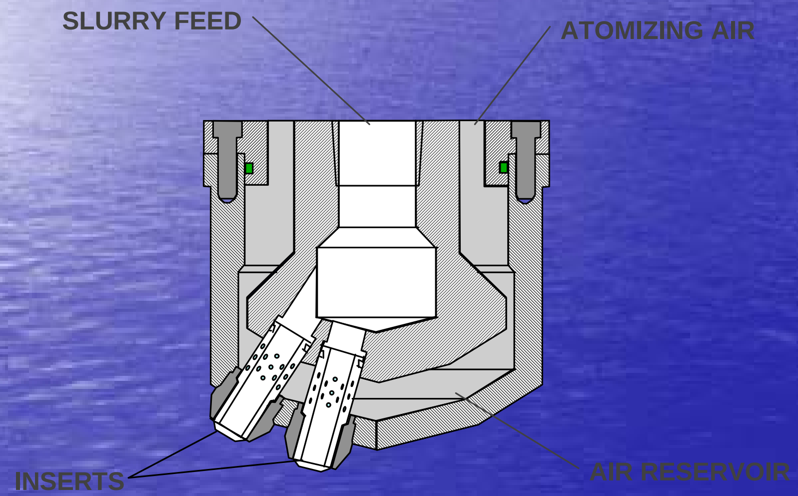
Rotary Atomizer

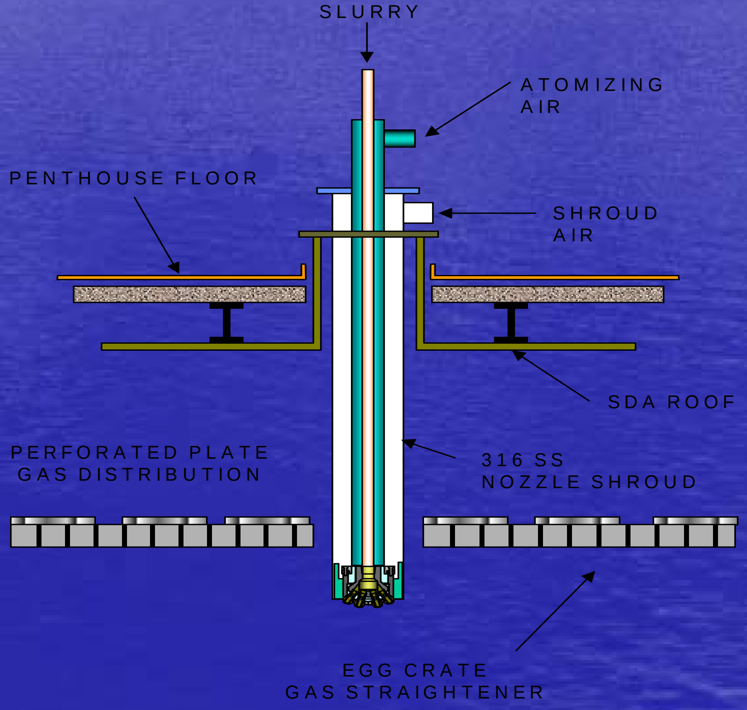
Dual Fluid Atomizer

- Dual Fluid Atomizer shows dispersion of slurry from nozzle
- Atomizers are supplied with quick disconnects to permit on-line maintenance
- Siemens design uses 15 – 20 dual fluid nozzles in a single vessel

Dual Fluid Atomizer

16-20 per absorber





FABRIC FILTERS
Principles of Operation

- Particulate Laden Gas Passes Through A Woven Or Felted Fabric
- Forces Of Impaction, Interception, And Diffusion Separate The Particles From The Gas Stream
- As The Process Proceeds Particles Will Impinge Upon Previously Collected Particles
- The Built Up Deposit May Itself Become The Collection Medium
- Dust Is Removed From The Media
- With an SDA or CDS System the Fabric Filter Can Account for Up to 20% of the SO_2 removed

Waste Recycle System

Waste Recycle System

- Waste Recycle System
  - To increase lime utilization
  - Recycle ash day bin (8 hours)
  - Distance between recycle slurry tanks and atomizers should be kept short
  - Current trend is to minimize retention time in recycle tanks
- Waste Storage Silo
  - Size based on amount of waste to disposal

Waste Storage Silo

Waste Recycle System

To increase lime utilization

4-8 hours storage silo

slurry mix tank

2 x 4 hours slurry storage tank

Deposits in the bottom of tank

>35% solid

3-4 day waste storage

Flue Gas System

Inlet/outlet ductwork

- Carbon Steel
- Keep Distance short between Absorber Outlet and Baghouse Inlet
- Minimize turns and direction changes

Chimney

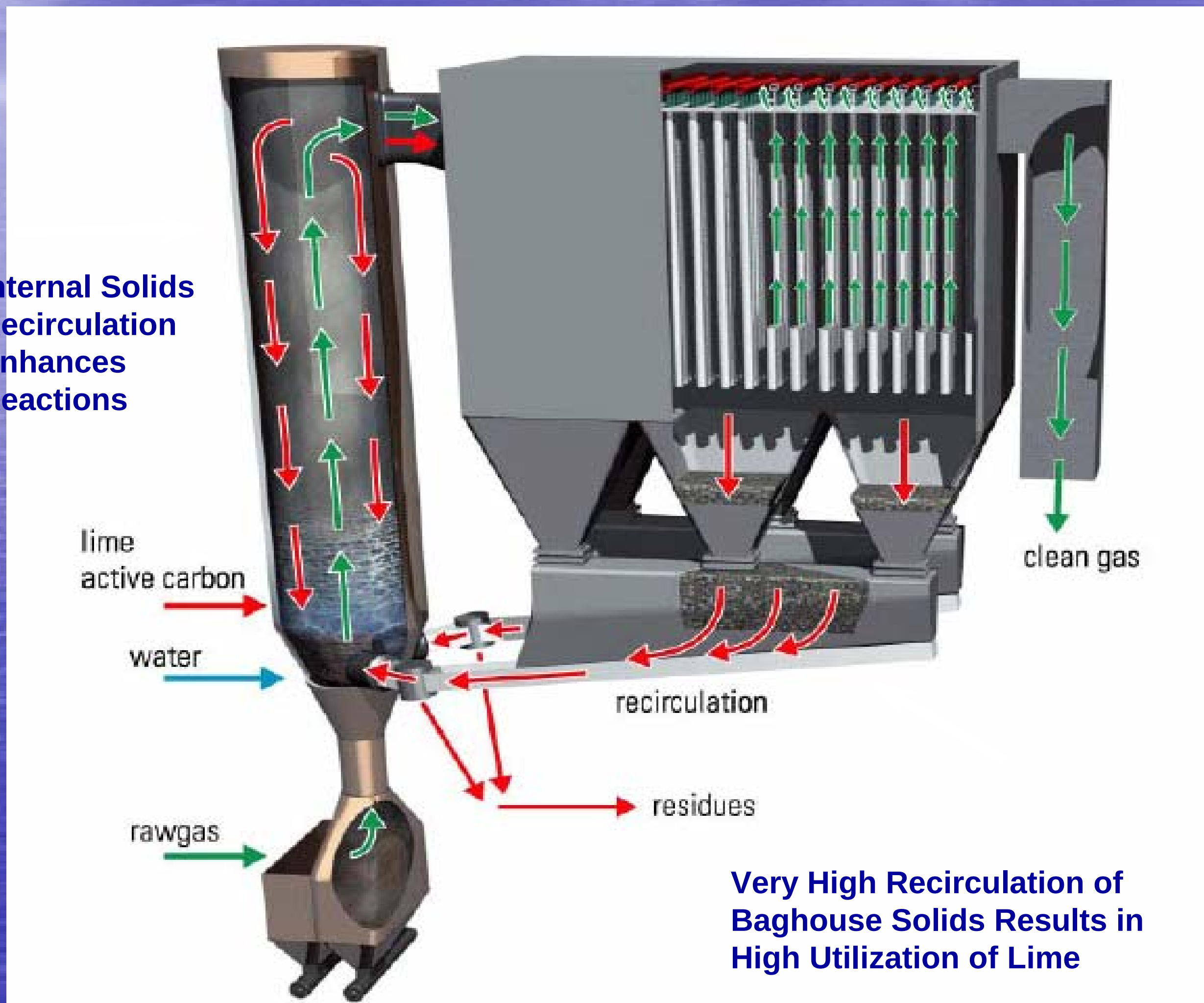
- Top 20’ wall papered with stainless steel (acid resistant coating is the lower cost option) requiring more maintenance
  - Typically low load velocities/possibility of cold air infiltration

Circulating Dry Scrubbers (CDS) or Circulating Fluidized Bed (CFB)

Circulating Dry Scrubber System

- The separate addition of water allows the CDS system to operate on somewhat higher sulfur fuels than the spray dryer technology
- CDS system is simpler in components and concept than the Spray Dryer
- Both technologies recycle large amounts of solids to help control lime consumption
- High efficiencies similar to a wet FGD are possible
- Low levels of emissions have been guaranteed in the past
- Lowest guaranteed emission – 0.040 lb/mmBtu

Circulating Dry Scrubber



Internal Solids Recirculation Enhances Reactions

Very High Recirculation of Baghouse Solids Results in High Utilization of Lime

Circulating Dry Scrubber System

- The absorber is a fluidized bed of solids suspended by flue gas
  - At low loads clean gas is recirculated to maintain solids suspension
- As opposed to the spray tower design CDS adds dry hydrate to the absorber
- Water is sprayed in separately in the fluidized bed to aid in collection

Dry FGD Technology Suppliers

- **Semi-dry FGD**
  - Alstom
  - Babcock & Wilcox
  - Siemens Environmental
- **Circulating Dry Scrubber**
  - Alstom
  - Babcock & Wilcox
  - Foster Wheeler (Graff Wulff)
  - Allied Technology
  - Babcock Power
  - Hitachi
  - Marsulex

DSI Technology Suppliers

- ADA-ES
- Babcock & Wilcox
- Clyde Bergemann
- F L Smidth
- FuelTech
- Nalco-Mobotec
- Nol-Tech
- Schick
- UCC

SO_2 Control – DSI

When Compared to other FGD Technologies

- Lower Capital Costs
- Higher Operating Costs for Reagent
- Smaller Footprint
- Ease of Installation (Installed in Existing Ducts)
- Only Moderate SO_2 Reduction (50% to 80% SO_2 Removal)

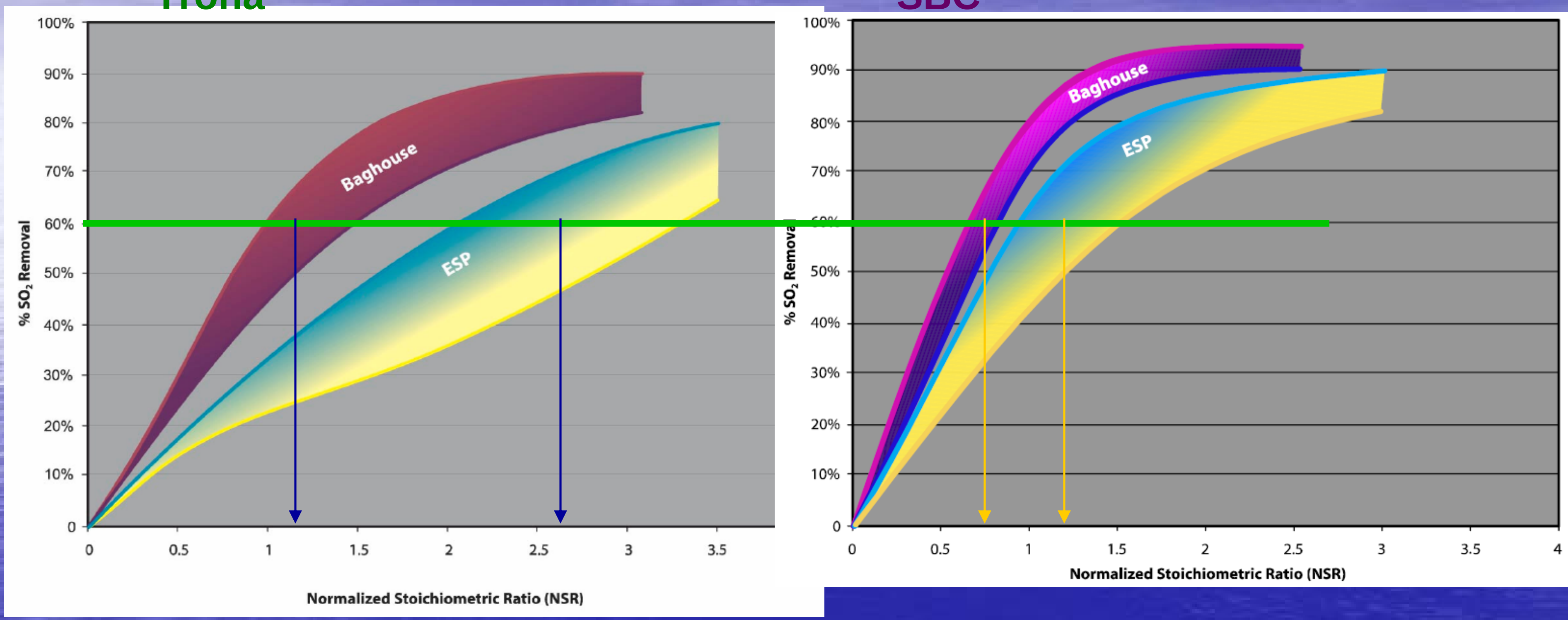
SO_2 Control – DSI

Calcium vs. Sodium

Calcium (Limestone or Lime)	Sodium (Trona or Sodium Bicarbonate (SBC)
1800°F to 2200°F Optimum for Furnace Injection	**600°F to 800°F Optimum for Trona** **250°F to 350°F Optimum for SBC**
Lime Could also be Injected After Economizer	**Dry Injection**
Some Reduced ESP Performance	**Improved ESP Performance**
Limited to ~50% SO_2 Removal	**Up to ~80% Removal**

SO_2 Control – DSI

Trona SBC



Example NSR at 60% Removal (Refer to Graphs Above)

Source: Solvay Chemicals

Sorbent	Trona		SBC	
Capture Device	**ESP**	**BGH**	**ESP**	**BGH**
NSR	**2.6**	**1.15**	**1.2**	**0.75**
Sorbent Increase by wt.	**3.1**	**1.4**	**1.6**	**1.0**

Questions?