System Design
Typical DFGD Installation

- Wet Flue Gas Desulfurization (WFGD)
- Pulverized Coal Boiler
- Selective Catalytic Reduction (SCR)
- Spray Dryer Absorber (SDA)
- Fabric Filter (FF)
- Low NOx Burners
- Air Preheater
- Induced Draft Fans
- Stack
Typical DFGD Installation
Typical DFGD Installation
DFGD Process Flow Lime Only

- Flue Gas
- Spray Dryer
- Fabric Filter
- I.D. Fan
- Disposal
- Water
- Lime
- Slaker
- Storage Tank
DFGD Process Flow Recycle

Flue Gas → Spray Dryer → Fabric Filter → I.D. Fan → Disposal

Lime → Water → Slaker

Water → Storage Tank → Feed Tank

Recycle Silo → Disposal

B
SDA Spray Cloud
Atomizing Key to the Process

- Fine Droplet Size
- Uniform Size Distribution
- Controlled Cloud Shape
- Optimum Gas/Liquid Mixing
- Stable and Controlled Temperatures
Rotary Atomizer

- **Inlet Gas Distributor and Atomizer**
  - Disk Rotates 8,000 to 13,000 rpm
  - <50 Micron Droplets Created by Centrifugal and Shear Forces
  - Each Atomizer Unit Operates Independently
Rotary Atomizer – CFD Model
Reactor Design

- Slurry drying and acid gas scrubbing
- 10 to 15 seconds gas retention time
- Reactors from 3 ft to 69 ft diameter
- Single or multiple atomizers
- Can be designed with an installed spare atomizer
- Physical and CFD models
Temperature Control

- Dry Bulb Temperature
- Wet Bulb Temperature
- Approach Temperature
Psychrometric Chart

- Adiabatic Saturation Temperature (AST)
- Dew Point Temperature
- ~43% Relative Humidity
- Inlet Flue Gas Moisture
- 30 °F Approach to Saturation Temperature
- Inlet Flue Gas Dry Bulb Temperature
- 30 °F dT
DFGD Reactions & Products

- **Lime Slaking**
  \[
  \text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2(s)
  \]

- **Acid Gas Scrubbing**
  \[
  \text{SO}_2 + \text{Ca(OH)}_2 \rightarrow \text{CaSO}_3 - \frac{1}{2}\text{H}_2\text{O} \ (s) + \frac{1}{2}\text{H}_2\text{O} \ (g)
  \]
  \[
  \text{SO}_2 + \text{Ca(OH)}_2 + \text{H}_2\text{O} + \frac{1}{2}\text{O}_2 \rightarrow \text{CaSO}_4-2\text{H}_2\text{O} \ (s)
  \]
  \[
  \text{SO}_3 + \text{Ca(OH)}_2 + \text{H}_2\text{O} \rightarrow \text{CaSO}_4-2\text{H}_2\text{O} \ (s)
  \]
  \[
  \text{CO}_2 + \text{Ca(OH)}_2 \rightarrow \text{CaCO}_3 \ (s) + \text{H}_2\text{O} \ (g)
  \]
  \[
  2\text{HCl} + \text{Ca(OH)}_2 \rightarrow \text{CaCl}_2-2\text{H}_2\text{O} \ (s)
  \]
  \[
  2\text{HF} + \text{Ca(OH)}_2 \rightarrow \text{CaF}_2 \ (s) + 2\text{H}_2\text{O} \ (g)
  \]
System Components
Reagent Preparation

- Lime Slaking Accomplished by:
  - Detention
  - Paste
  - Milling
  - Slaking must take place at high temperature

- Final Slurry Preparation Combines
  - Lime Slurry
  - Dilution Water (waste water)
  - Dry Recycle (optional)
Lime Quality

a. **Particle Size:** 3/4” x 0” with no more than 50% less than 10 mesh.

b. **Availability:** 90 % CaO or greater as measured by ASTM Method C25.

c. **Reactivity:** Greater than 40 °C temperature rise at three minutes as measured by ASTM Method C110.
Lime Slaking Guidelines

- Slaking Temperature - 175°F +/-
- Diluted to 20% solids
- Filtered to 20 mesh or less
- Settled Volume after 24 hrs >50 ml @ 10% solids
Paste Slaker
Detention Slaker
Vertical Mill Slaker
Reagent Preparation Area
Lime Slaking and Storage
Alstom SDA
Flue Gas Inlet Ducts
B&W SDA
Gas Disperser
Multiple Atomizers

- Each Atomizer Acts Independently
- Excellent Interface Between Flue Gas and Lime Spray for SO$_2$ Collection
- Three atomizers per SDA
- Optional operation with two out of 3 atomizers at full load
- Turndown to 10% load
- Designed for 12 Second Retention Time
Rotary Atomizer
Rotary Atomizer Assembly

- Each has up to 150 MW flue gas scrubbing capacity
- 450 MW Capacity Spray Dryer with 3 Atomizers
- Assembly Can Be Hoisted Up While the Spray Dryer is in Operation
- Proven Reliable Design 30 years of power plant service
- Over 150 Rotary Atomizers in Operation
Rotary Atomizer Assembly

- US manufactured
- 150+ Machines in daily service
- 40 Locations
- 60 – 400 hp
- 8,000 to 15,000 rpm
Rotary Atomizer

- Reliable Operation:
- Vibration Monitors are Standard
- Sophisticated Lubrication System with Filters and Coolers
- Careful Selection of Bearings and Gearbox Components
- Quick Removal from Spray Dryer Vessel for Inspection and Service
Rotary Atomizer Disk

- Nozzle
- Slurry In
- Wear Plates
- Shaft
- Atomized Spray
- Disk
Fabric Filter as a Chemisorption Device

Applications:

- $\text{SO}_2$, $\text{SO}_3$, HCl, HF, Dioxin, Mercury Removal
- Spray Dryer
- Dry Injection
- Lime, Sodium Bicarbonate, Carbon

SO$_2$ and HCl Removal with Spray Dryer
• Important part of DFGD
• Reaction
  – Second Stage SO2 Removal
  – Patented Process (No. 4,197,278)
• Collection
  – Fly ash
  – Reaction Products
FF Compartment Plan View
Rotary vs. Dual Fluid Atomization
Dual Fluid Nozzle Atomization

• Air is Used to Atomize the Slurry to Fine Droplets
• Droplet Distribution 20 to 60 Microns
• Abrasion Resistant Nozzle Tips Ensure Long Life
Dual Fluid Nozzle Gas Disperser

- Lime Slurry is Atomized by Compressed Air
- Individual Nozzles Can Be Removed While the Spray Dryer is On-Stream
- Spray Pattern is Tailored to the Spray Dryer Vessel Configuration
Nozzle Spray Dryer Gas Inlet

- Flue Gas is Balanced and Directed to Individual Nozzle Assemblies
- Turning Vanes Ensure Equal Gas Distribution at the Nozzle Tips
Nozzle Spray Dryer Gas Distribution

- Equal Gas Distribution at Each Nozzle Ensures Even Gas Distribution at the Reactor Bottom
- Multiple Nozzles Minimize Flue Gas “Bypass” Inside the Reactor
- Gas Flow Evens Out as the Gas Flows Downward Toward the Bottom Outlet
Dual Fluid Nozzle Disadvantages

- Limited slurry flow rate per nozzle requires many nozzles and complex piping
- Each rotary atomizer has 10x larger capacity thus fewer are needed
- Air compressors are inefficient
- Much of the energy in the compressed air is wasted by the nozzle
- Rotary atomizers are over 90% efficient
- Power savings can be over a MW
Atomization design of Major suppliers of Dry FGD

- Original Developers of DFGD in 1978
  - Joy / Niro - Rotary
  - B&W - Nozzle
  - Rockwell - Rotary
  - CE - Both
  - Carborundum - Nozzle
  - Flakt - Nozzle

- Consolidation over past 30 years
  - B&W - Rotary
  - Alstom - Rotary

- Over 90% of all DFGD systems use Rotary Atomizer
Spray Dryer Alternatives
Flash Dryer Process Concept

- Very High Solids Recirculation
- No Slurry Handling
- “Dry” Product
- High Utilization of Reagent
Flash Dryer Absorber

- Modular design
- Operations are closer to grade
- High Reliability
- Approximately 1.2 seconds gas residence time
- No high pressure or high speed atomizers
- No slurry handling
FDA Multiple Module System

- Each Mixer Acts Independently
- Excellent Interface Between Flue Gas and Humidified Recycle for SO\textsubscript{2} Collection
- Continuous Recirculation with Air Slides and Fluidized Troughs
- Controlled Water to Recycle Ratio
- Dry Waste Product Calcium Sulfite/Sulfate
FDA History

- Pilot Plant at Univ. of Tennessee – 1988
- Pilot Plant at TVA Shawnee – 1992
- European pilots – 1995
- Full Scale Laziska Retrofit - 1996
- Currently 62 installations - over 6000 MW
FDA / Fabric Filter (3 x $120 \text{ MW}_e$)
AES Fifoots Point PS, Wales, UK
Reliant - Seward Station
Flash Dryer Absorber (FDA)
FDA + ESP 70 MW

Zhejiang # 8, PRC
FDA/ESP
Juhua Group / ZCE Boiler No. 8, Zhejiang, PRC
FDA – Advantages

- Low investment
- Less Equipment
  - Spray dryer
  - Slurry handling equipment
  - less maintenance
- Reduced power consumption
- Compact reactor design housed under the particle collector
- High SO$_2$ removal efficiency