REINHOLD ENVIRONMENTAL Ltd.

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FOSTER WHEELER

Circulating Fluidized Bed Scrubbing Technology

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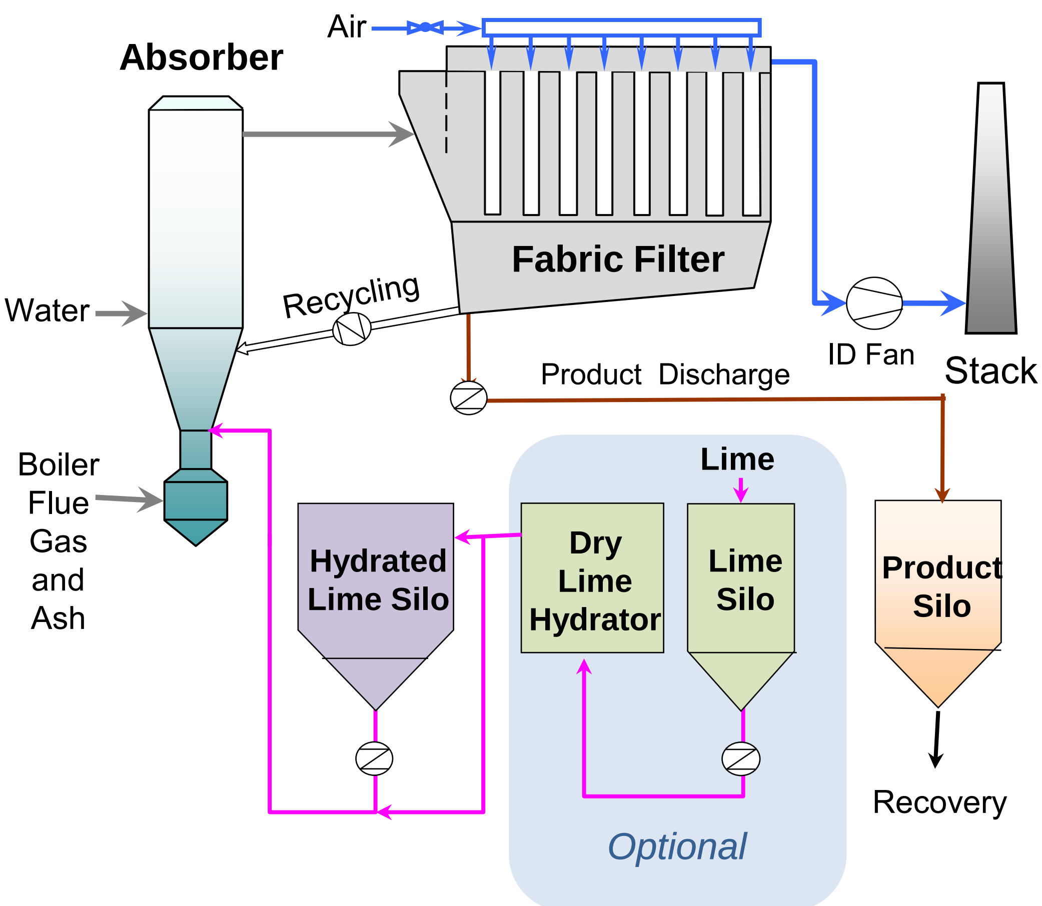
Circulating Fluidized Bed Scrubbing (CFBS) Technology

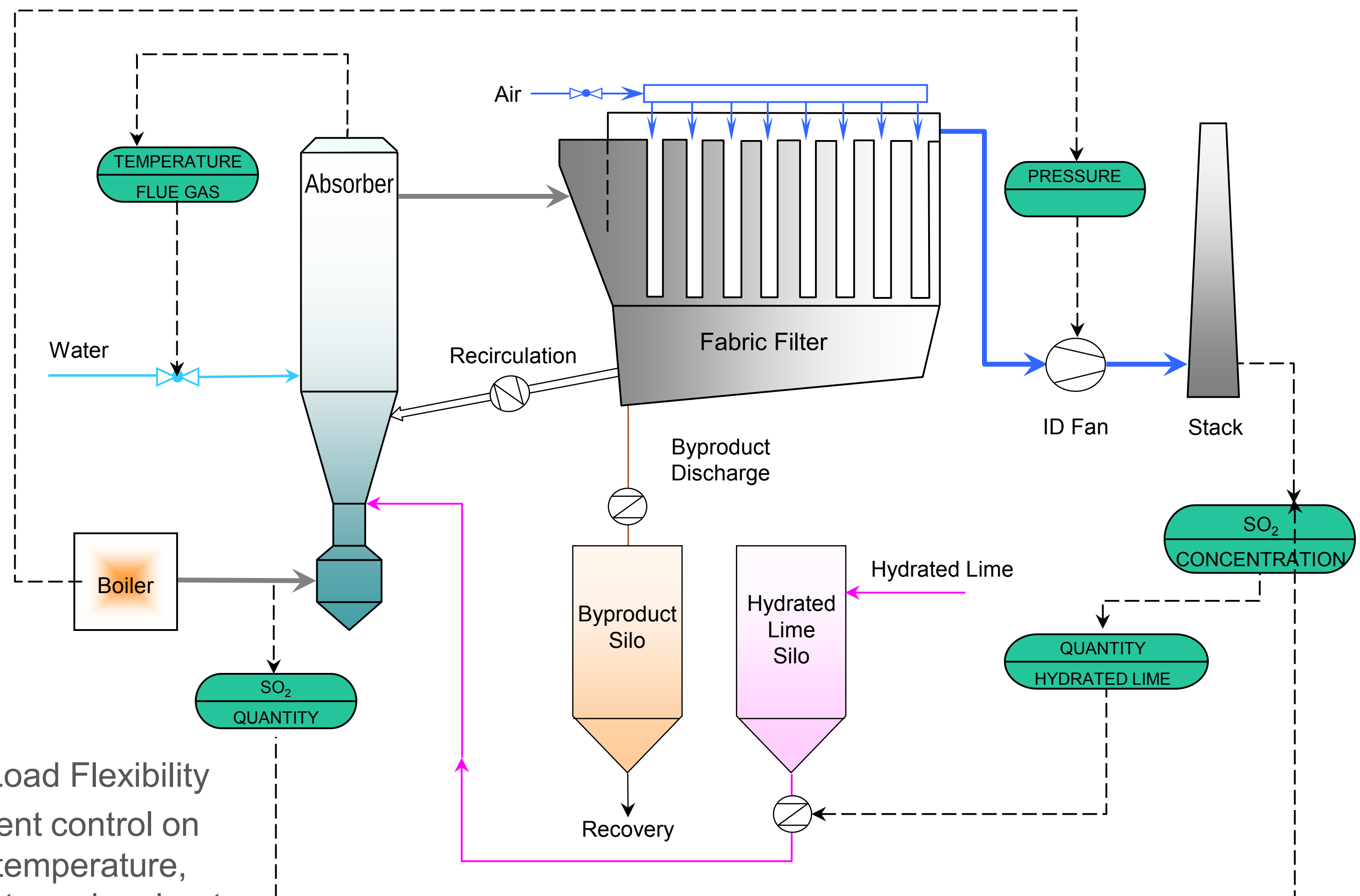


Flexible, reliable multi-pollutant capture with minimal water consumption

How does it work?

- Flue gas with or without ash enters the bottom of the absorber, flowing upward through venturi to accelerate the gas flow causing turbulence flow.
- Recycled solids, hydrated lime and water mix with the turbulent flue gas providing gas cooling, reactivation of ash and capture of pollutants.
- The gas and solids enter the baghouse where solids are captured and recycled back to the absorber to capture more pollutants
- Reactive absorbents like activated carbon or others can be added to target specific pollutants
- Optional dry lime hydrator produces hydrated lime on-site from lower cost quick lime

Independent Reagent and Water Control Provides Widest Capture Range and Minimal Water Need



Fuel and Load Flexibility

Independent control on flue gas temperature, recycling rate and sorbent injection.

Essentially, Three (3) Control Loops

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CFB Scrubber Achieves High Capture of Multiple Pollutants

- Typical Performance for Circulating Fluidized Bed Scrubbers

<table>
<tr><th>Pollutant</th><th>Removal Rate</th><th>Notes</th></tr>
<tr><td>SO_2 and SO_3</td><td>Up to 99%</td><td></td></tr>
<tr><td>HCl</td><td>85 – 99%</td><td></td></tr>
<tr><td>HF</td><td>99%</td><td></td></tr>
<tr><td rowspan="3">Hg [1]</td><td>50 – 70%</td><td>Low halogen PRB coal – Based on Basin</td></tr>
<tr><td>80 – 90%</td><td>With Eastern Bitumous Fuels (high in Halogens)</td></tr>
<tr><td>90 – 99%</td><td rowspan="2">With Activated Carbon Injection (ACI)</td></tr>
<tr><td>Dioxines, Furanes [1]</td><td>95 – 98%</td></tr>
</table>

1) Total of all compounds in all phases expressed as elements

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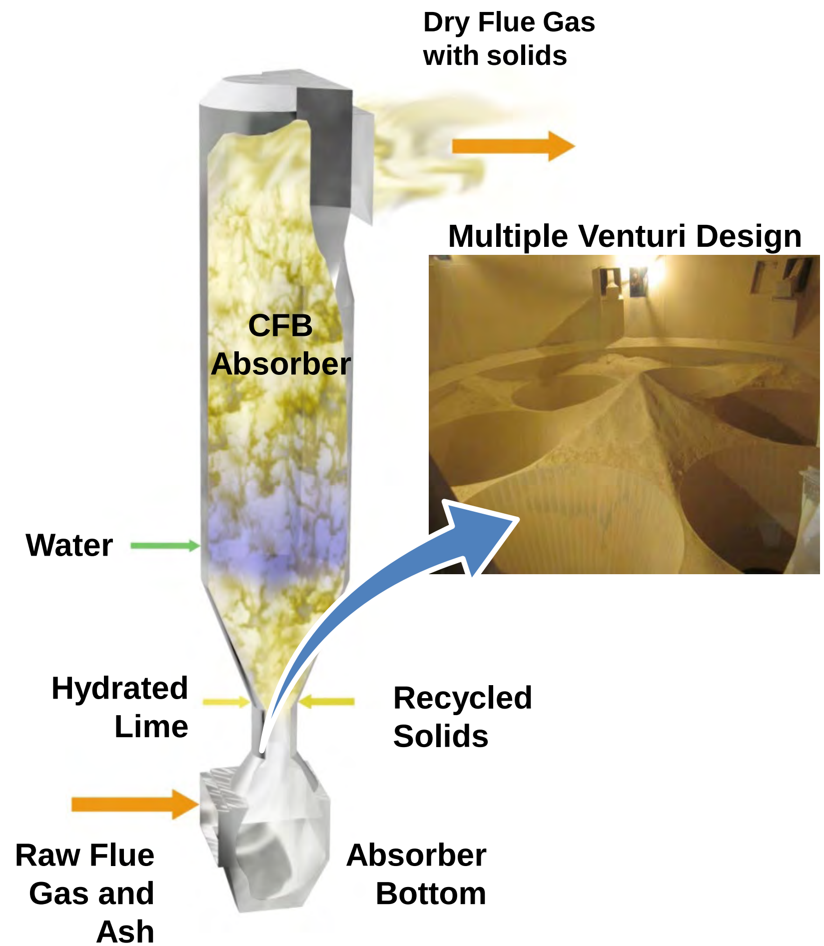
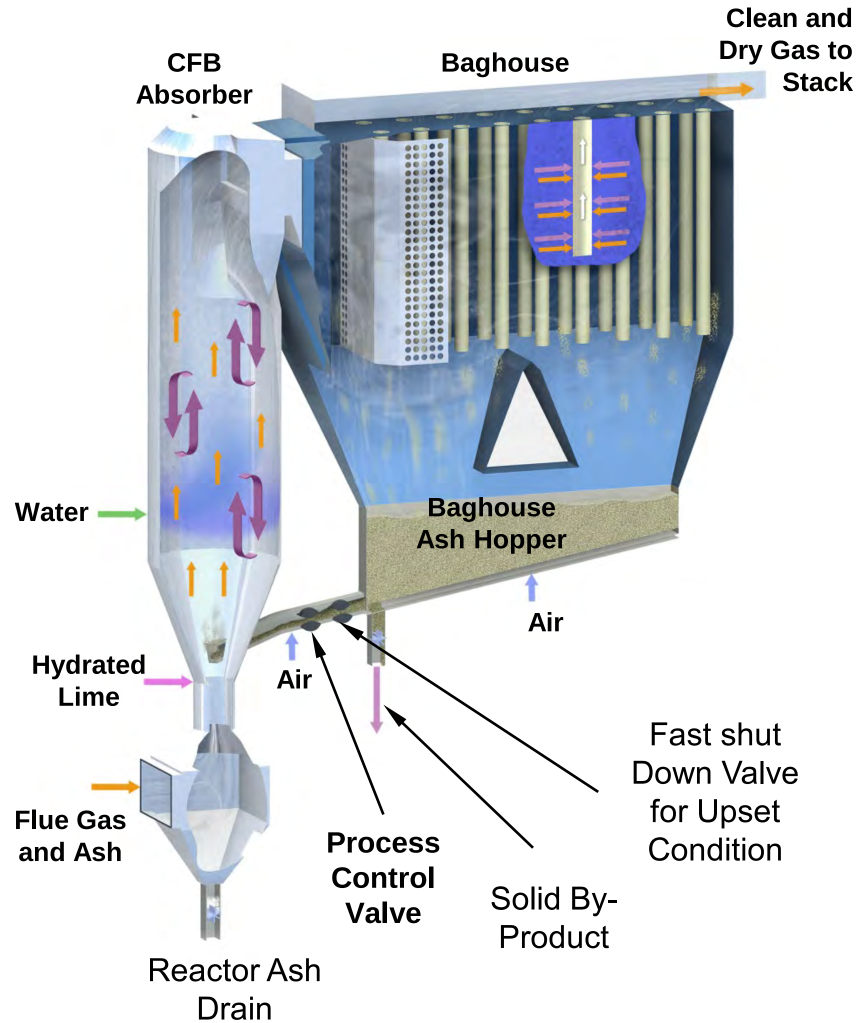
Design Features of CFB Absorber

- Turbulent CFB absorber provides optimized conditions for multi-pollutant capture
  - Flue gas is efficently mixed with hydrated lime and water for 4-6 seconds (other single pass technologies have residence times of approximately 1 sec)
  - Wall turbulators Increase turbulence near wall
- Flexible process provides wide performance and load range
  - Hydrated lime injection not limited by gas temperature to achieve high pollutant capture
  - Solids and water injected above venturi to ensure high turbulant mixing at low loads
- Low Maintenance
  - No mechanical lime spray heads to maintain
  - Solid circulation keeps reactor surfaces clean
  - Absorber bottom allows easy solids removal for maintenance
  - Low maintenance water nozzles can be replaced while unit is online
- Single absorber designs up to 700 Mwe



Baghouse and Solid Circulation Design Features

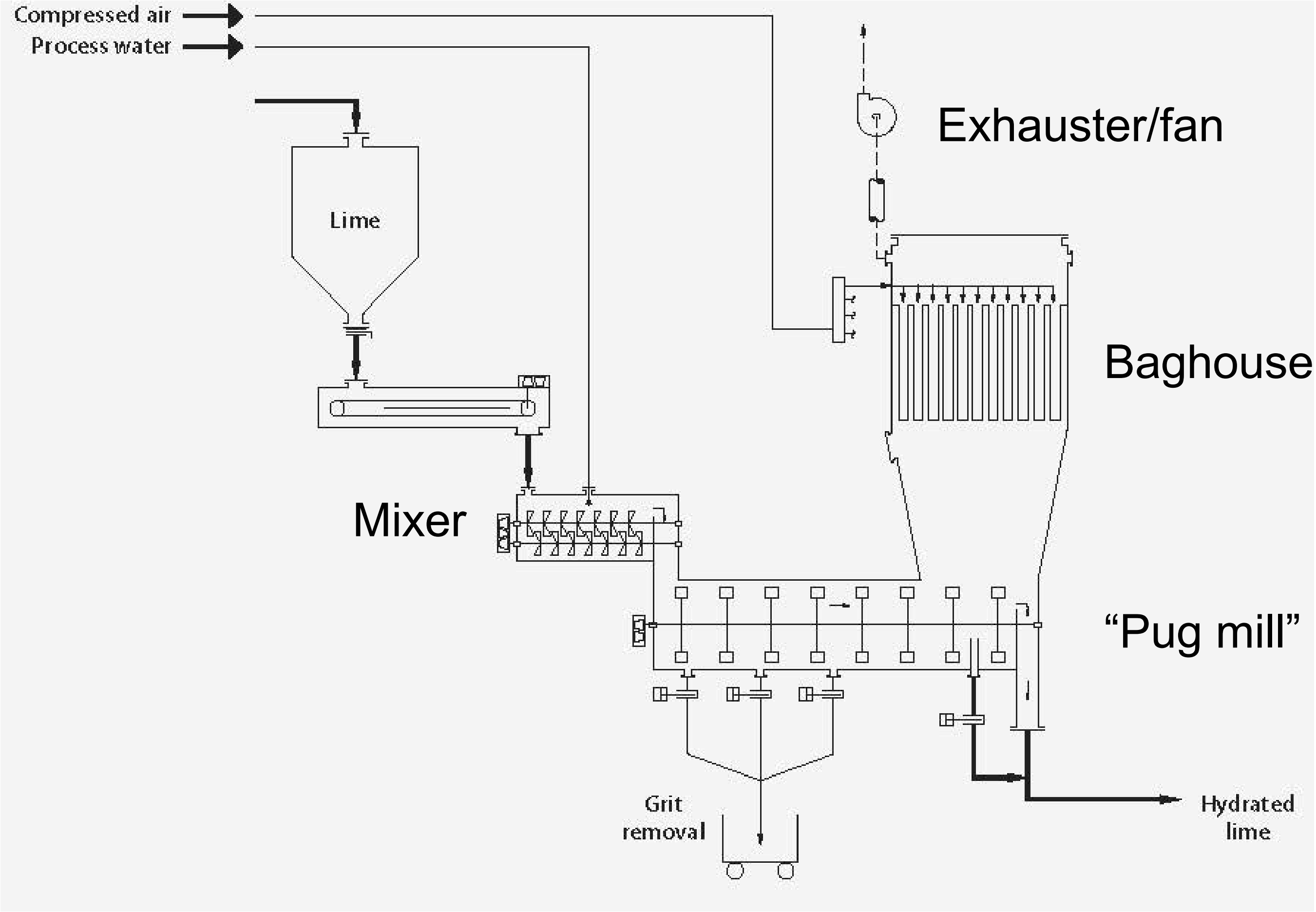
- High Utilization of Sorbents
  - Circulating solids can keep reagents in system up to 20-30 minutes
- Fluidized ash storage in baghouse hopper
- Highly reliable low maintenance air slide
  - No mechanical paddle mixer with their associated maintenance and reliability issues
  - Fast shutdown valve for automatic purging of absorber solids during upset
- Multiple compartment baghouse - typical
  - Low inlet (can) velocity allows high dust loading while maintaining low pulse frequency and long bag life
  - Bag filter cake captures vapor phase metals, acid gases and ammonia slip
- Dry sorbent and product are easy to handle
  - No slurry preparation, handling, dewatering, liquid waste streams
  - Stable dry by-product can be used for land restoration, road base or landfilled



Lime, Quicklime (CaO), Hydrated Lime ($Ca\{OH\}_2$) & On-Site Hydration

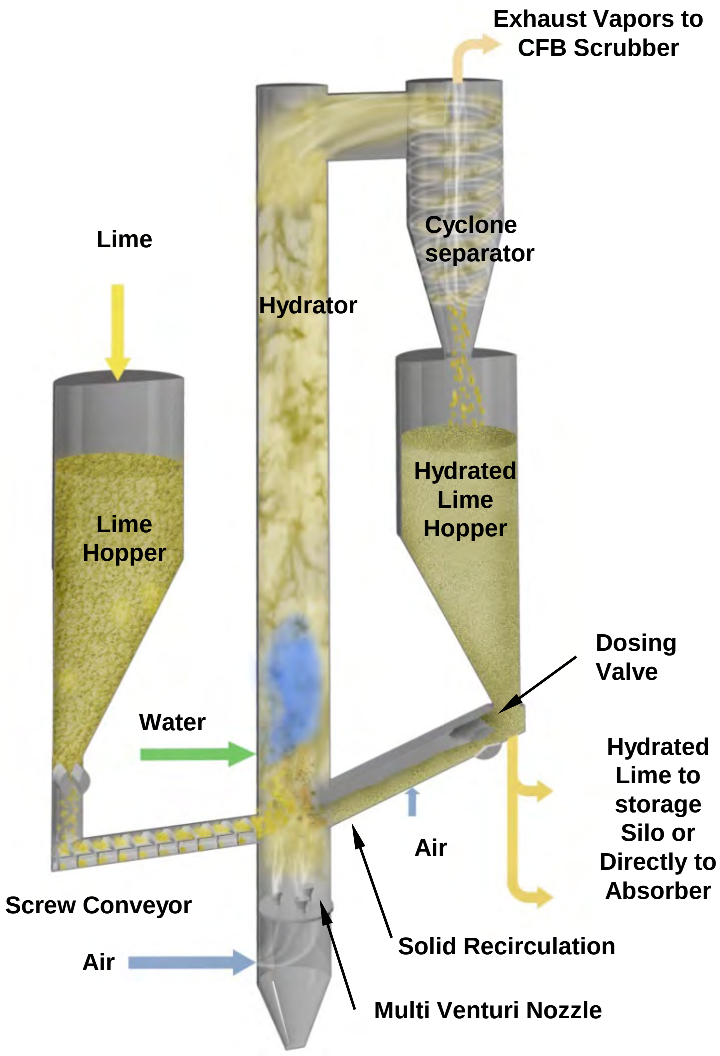
- "Lime" is a generic term – usually refers to either quicklime or hydrated lime
- Quicklime is produced from the calcination of limestone
- CFBS process requires hydrated lime
  - Direct purchase/injection of Hydrated Lime
  - On-Site Hydration of Lime
- Economic considerations
  - Quicklime is less expensive
  - Δ$ approximately $20-30/ton
  - Dependent on location
- On-site hydration

Mechanical Hydration

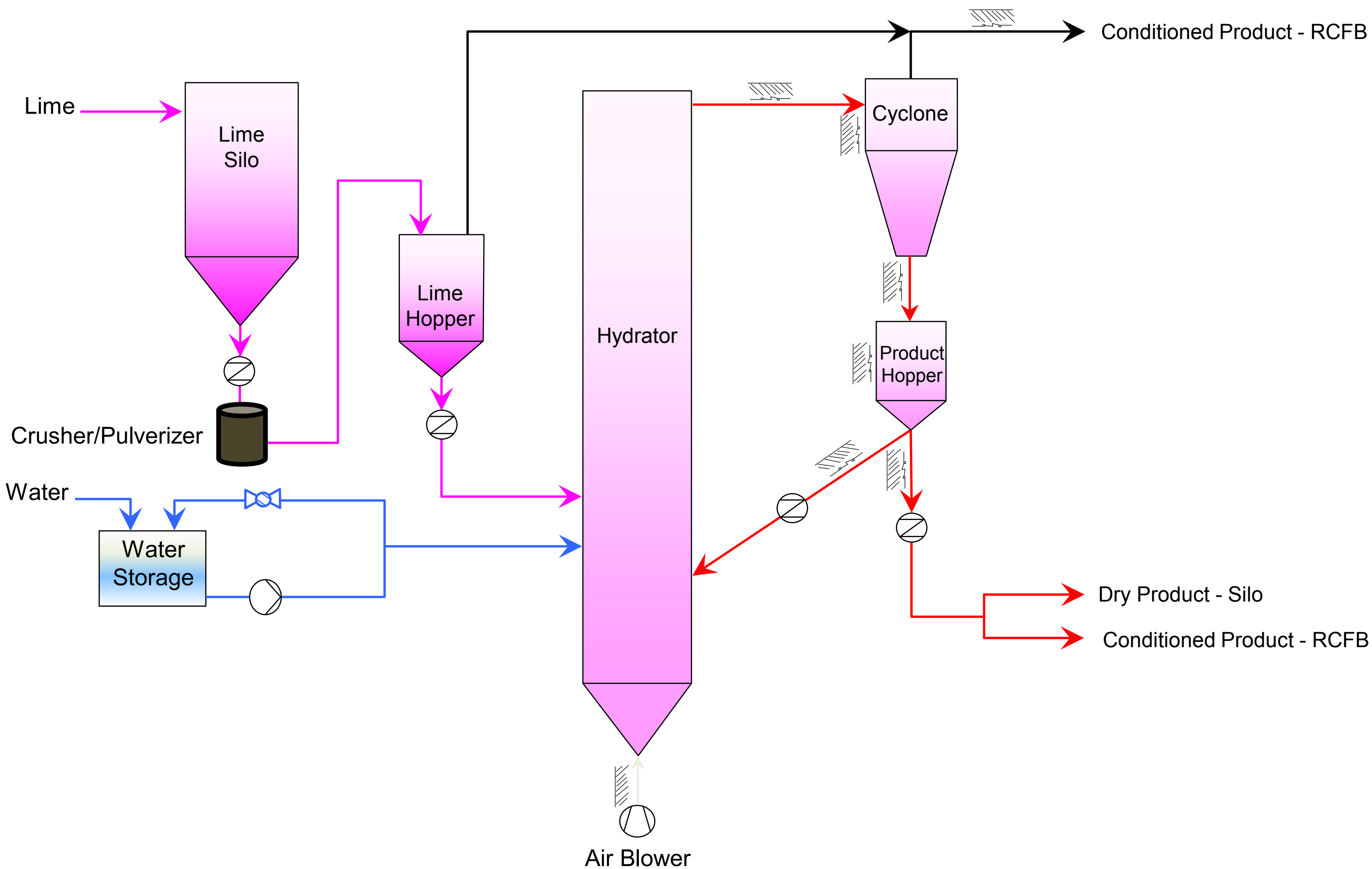


Fluidized Bed Lime Hydrator

- Produces high quality hydrated lime from economical quick lime
  - High hydrated lime BET surface area improves capture efficiency and lime utilization
- Low maintenance and reliable hydrator
  - No mechanical mixers
  - No rotating parts (except screw conveyor)
  - No slurry handling
  - No exhaust fabric filter or point source emission
- Operational Flexibility Potential
  - Hydrator turn down to 25%
  - Adjustable $Ca(OH)_2$ Reactivity Range
    - Higher moisture level when direct feeding to CFB absorber for higher reactivity
    - Lower moisture level for stable silo storage



Process Diagram of Lime Dry Hydration (LDH) Plant



Hydrator Differences/Benefits

Circulated Fluidized Bed Mixing

- Advantages:
  - homogenized mixing in the fluidization bed
  - stable and continuous operation
  - flexible and adjustable operation parameters if lime quality change
  - continuously produced high quality
  - safe control of hydration rate
  - high reliability and availability due to a minimized use of rotating parts
  - optimized for power plant applications
  - No additional bag filter due to integrated operation concept
  - Hydrator grit transferred to absorber
- Disadvantages:
  - slightly higher energy consumption due to fluidized air, pulverizer/crusher

Mechanical Mixing

- Advantages:
  - slightly lower energy consumption
  - higher throughputs available
- Disadvantages:
  - agglomeration of material
  - hydration rate difficult to control
  - requires stable lime quality conditions
  - requires intensive operation monitoring
  - requires **frequen**t cleaning services
  - higher maintenance for rotating parts (e.g. gears, paddles) required
  - requires additional bag filter for exhaust – **permit source**
  - Impurities (grit) has to be taken out of the mixer frequently

CFB Scrubber Technology Advantages

Wet FGD, Spray Dryer FGD, Circulating Fluid Bed FGD

	Wet FGD	SDA FGD	CFB FGD
SO_2 Capture to Meet Low Permit Limits	Advantage	Disadvantage	Advantage
Low Water Consumption	Disadvantage	Advantage	Advantage
Fuel Flexibility (Fuel Sulfur Variability)	Advantage	Disadvantage	Advantage
Fine Particulate Capture	Disadvantage	Advantage	Advantage
High SO_3 Capture Efficiency	Disadvantage	Advantage	Advantage
Mercury Capture	Disadvantage	Neutral	Advantage
Compact System Footprint	Disadvantage	Neutral	Advantage
Minimal Maintenance Requirements	Disadvantage	Neutral	Advantage
Overall			Advantage

Advantage (green) Neutral (blue) Disadvantage (red)

Source: Basin Electric/Sargent & Lundy Study

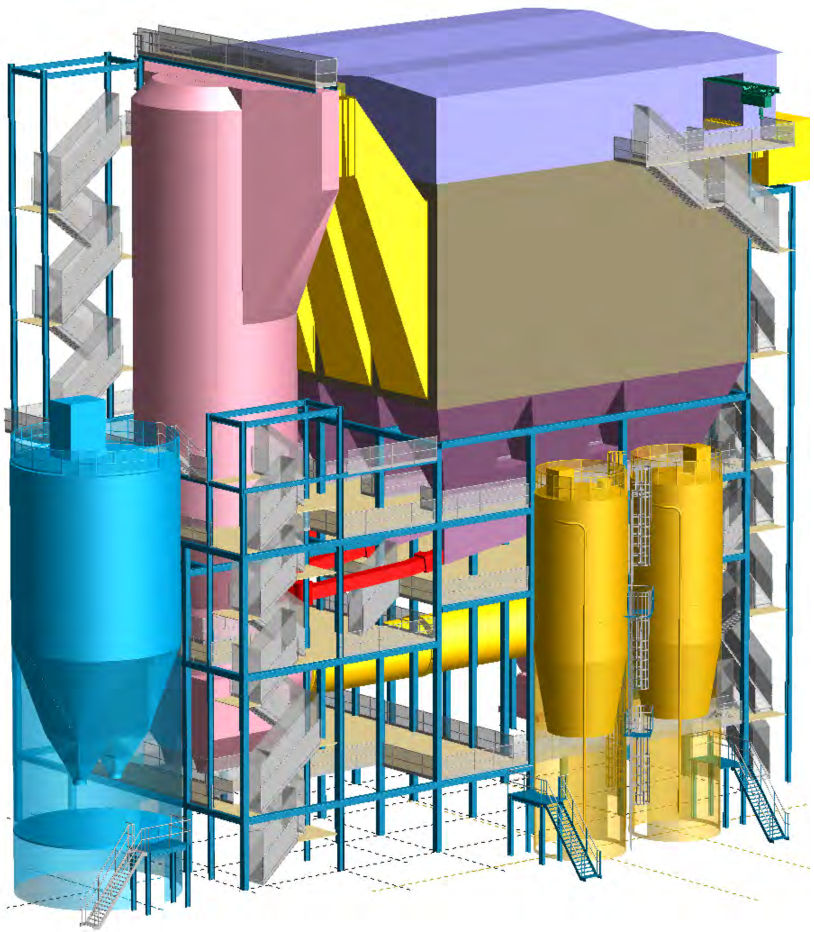
Largest CFB Scrubber is at Dry Fork Station

- Plant Location: Gillette, Wyoming, USA
- Plant Elevation ft (m): 4,300 (1,300)
- Customer: Basin Electric Power Cooperative
- Plant Start-Up: June 26, 2011
- Plant Electrical Output: 420 MWe (520 MWe@SL)
- Fuel: PRB Coal
- Scrubber configuration: 1 Reactor, 1 Fabric Filters
- Fuel Sulfur Content: 0.2-0.9% a.r.

Plant MCR Load	Inlet	Outlet	Removal %
Flue gas flow, ACFM (Nm3/h)	1,792,000 (1,580,000)	1,550,000(1,690,000)	
SO2 lb/MMBtu (mg/Nm3)	0.30-1.79 (350-2,200)	0.06 (60-75)	80 - 97%
SO2 ppmv	130-770	20-25	77 - 97%
SO3 ppmv (mg/Nm3)	8-14 (25-42)	0.3-0.6 (1-2)	96%
HCl ppmv (mg/Nm3)	5-9 (8-15)	2-3 (4-6)	60 - 67%
Dust lb/MMBtu (mg/Nm3)	3-5 (4,000-6,000)	0.012 (12-17)	99.6 - 99.9%
Temperature °F (°C)	294 (146)	155-175 (70-80)	

Definition of standard: 68°F, 14.7psig

On-going Product Development Efforts



Foster Wheeler has been active in advancing the technology through R&D efforts

Some initiative items include;

- Hg speciation measurement
- Absorber operational temperature optimization
- Hydrator Optimization
- PAC injection location optimization

Mercury (Hg) Reduction

CFBS has inherent Hg capture capabilities…

- With and without Powder Activated Carbon (PAC) injection
- However it is highly dependent on fuel (halogen content, Hg content, speciation, etc.)
- Injection location considerations
- Hydrator Optimization
- Halogenation
  - PAC
  - Fuel
  - Flue gas

PAC Consumption can be a significant evaluation factor

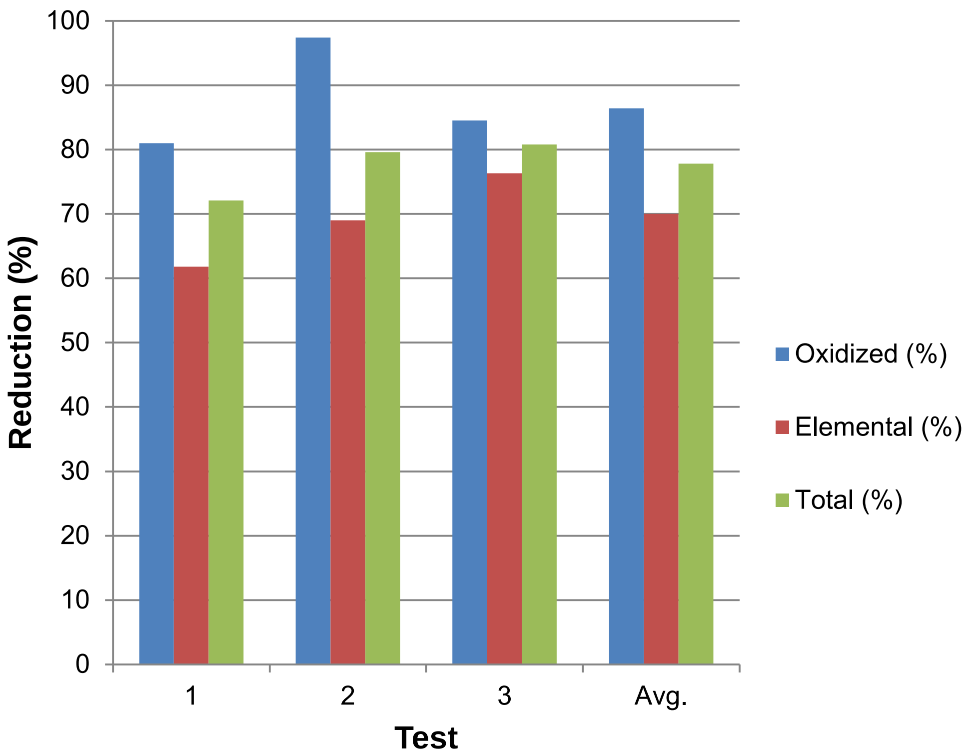
Mercury Reduction Capabilities

Foster Wheeler's Hg reduction initiative…

- Several units (PC, CFB)
- Different fuels
- Hg speciation
- PAC injection location

Preliminary Data (at right) showing Oxidized, Elemental & Total Hg reduction

NOTE: No PAC injection



Absorber Operation Temperature

The absorber operational temperature is usually referenced to as the *"approach to saturation temperature"*

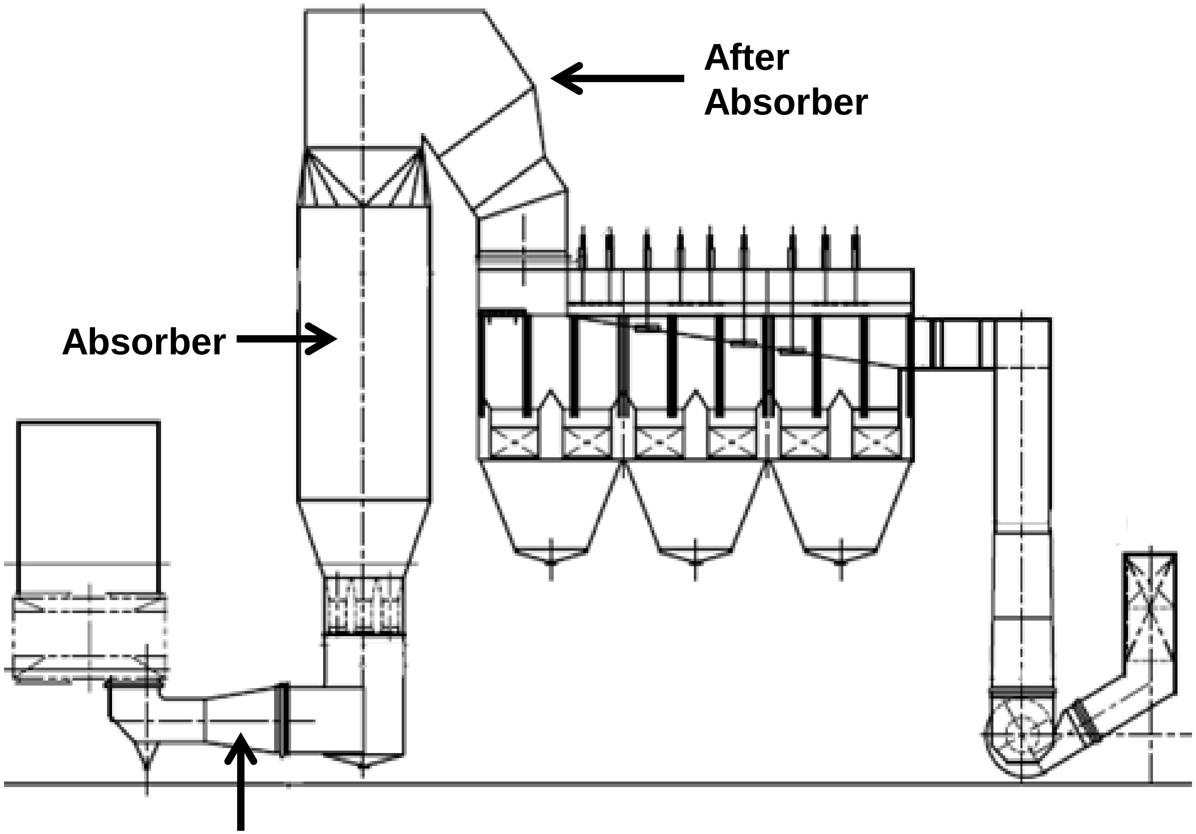
Typically Limited to +30 F

Impacts include:

- Lime Usage (Ca/S)
- Agglomeration/deposits
- Corrosion

Consequently, there are "trade-offs" in operation

PAC Injection Location



Before Absorber

High(er) Temperature

SO3 Concerns

In Absorber

Temperature Lower

No SO3 Concerns

Residence Time Sufficient?

After Absorber

Temperature Lower

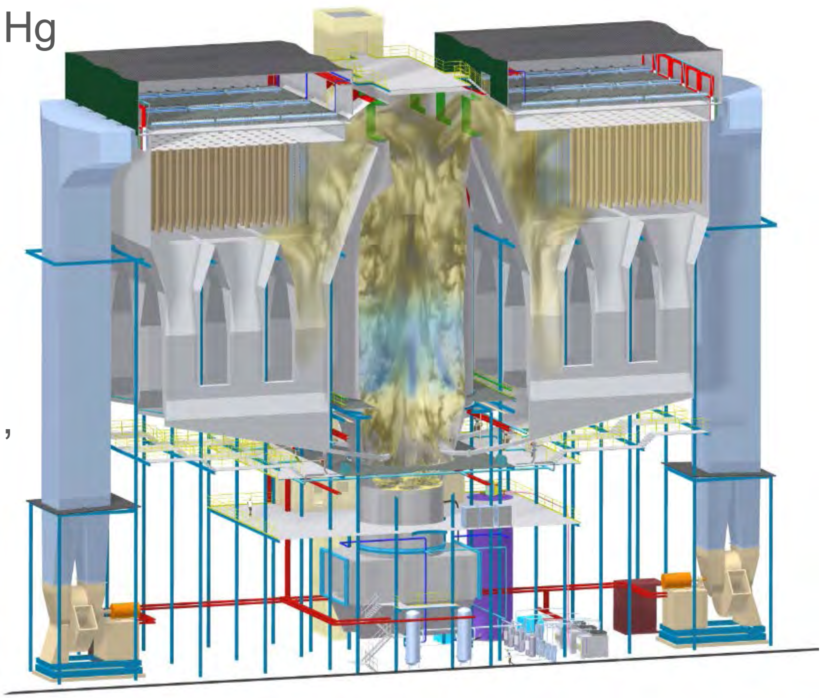
No SO3 Concerns

Residence Time Sufficient?

Space Available?

Advantages of CFB Scrubber Technology

- High Multi-Pollutant Capture Capability
  - Up to 99% Capture of SO2, SO3, HCl, HF, Hg
- Low Installed Cost
  - 50% less than wet FGD
- Low Water Use
  - 30- 40% less than wet FGD
- High Reliability and Low Maintenance
  - No slurry preparation, handling, dewatering, liquid waste streams
  - No mechanical atomizers or spray heads
  - No paddle mixers
- Compact Foot Print
- High Operational Flexibility
  - Capture not limited by flue gas temperature
  - Lower cost lime can be used with Hydrator
  - Ability to use low-quality lime and water



Basin Dry Fork Unit Provides Proven Reference at 525 MWe for SINGLE absorber vessel designs

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Thank You For Listening