Wet FGD System Overview and Operation

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WPCA Wet FGD Seminar
Power Gen International
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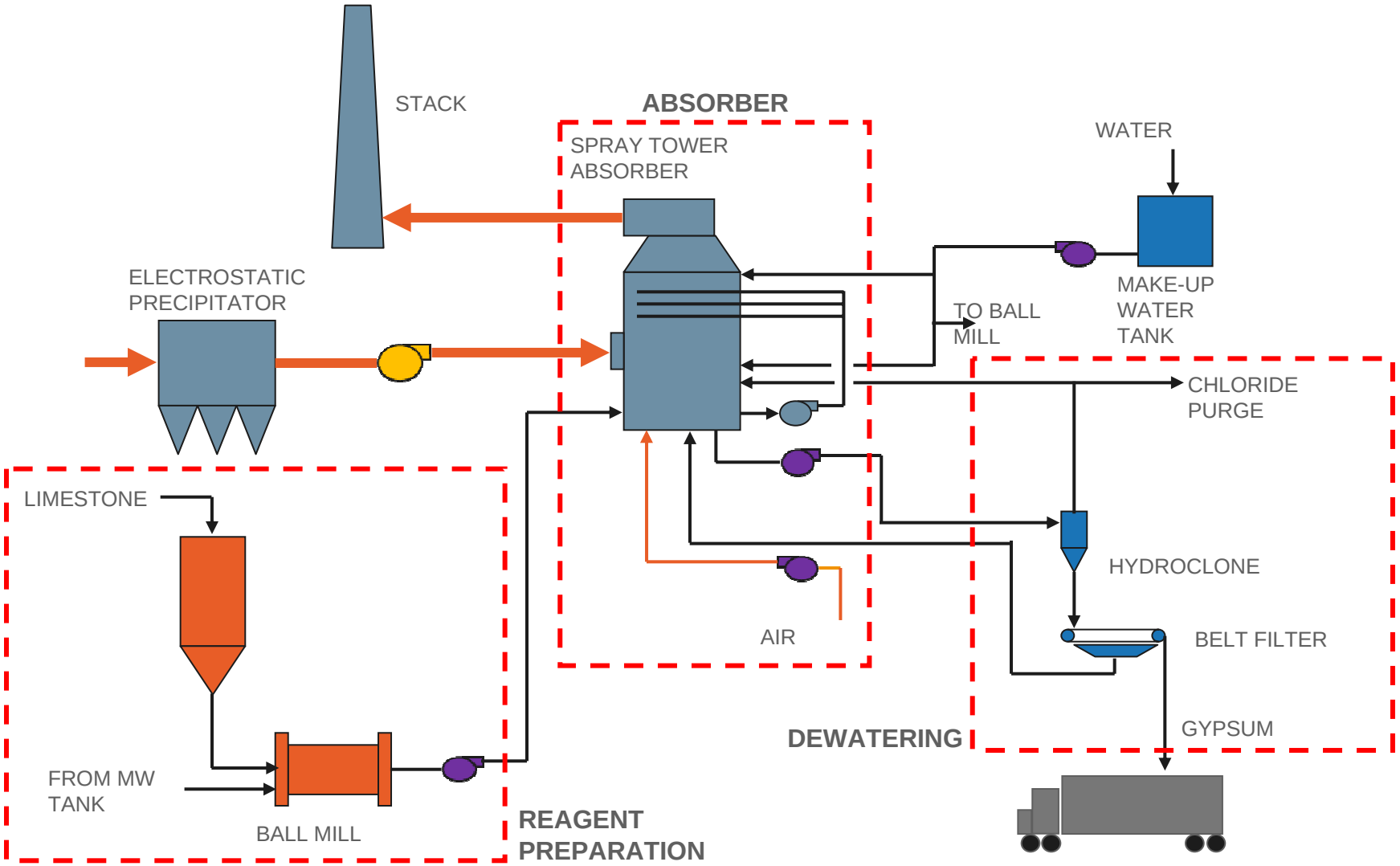
ALSTOM

Agenda

- Introduction
- Major Process Equipment
- Balance of Plant Equipment
- Controls
- Summary

Process Flow Diagram



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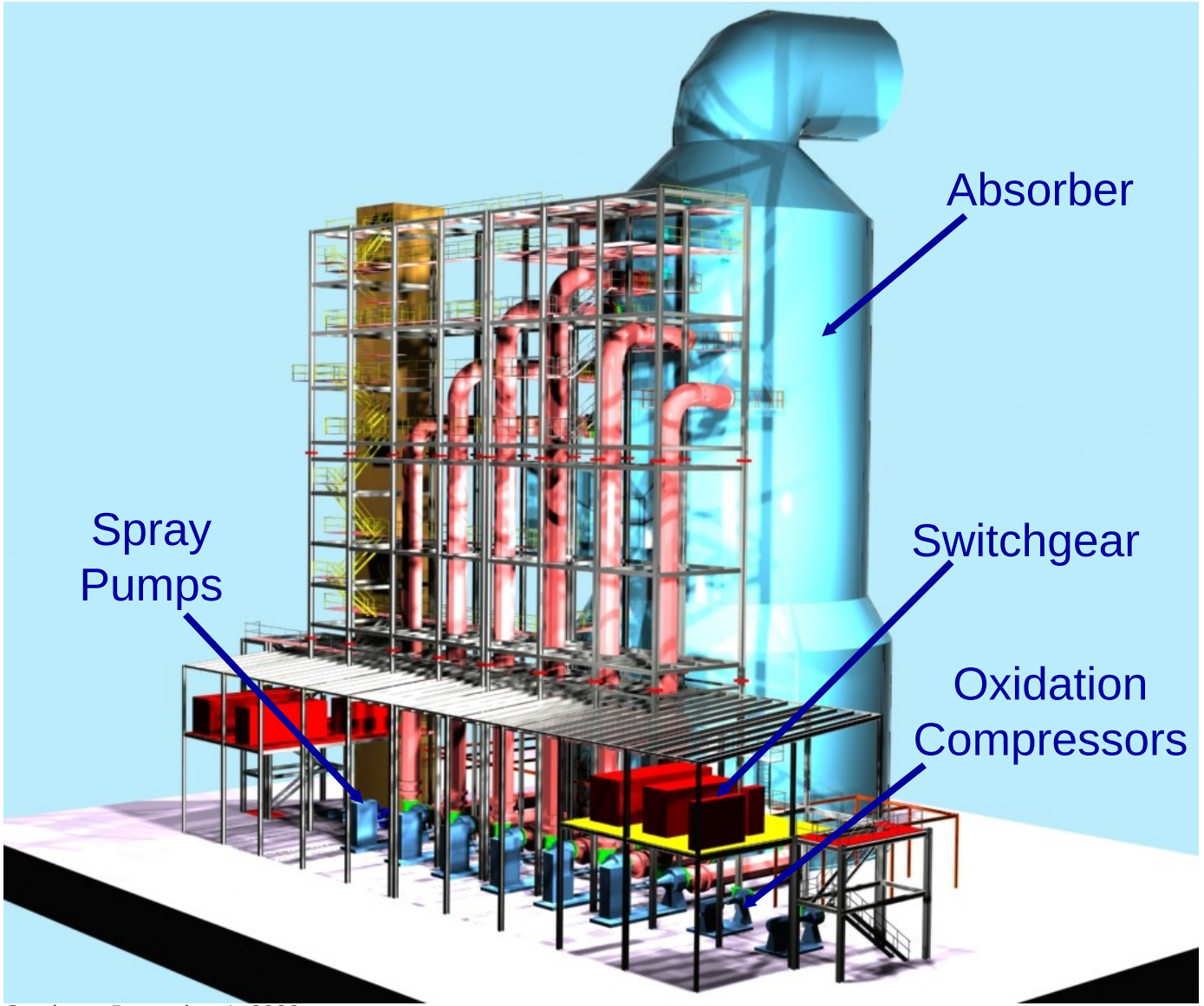
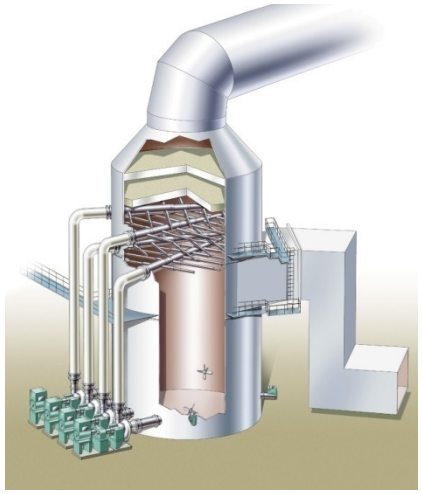
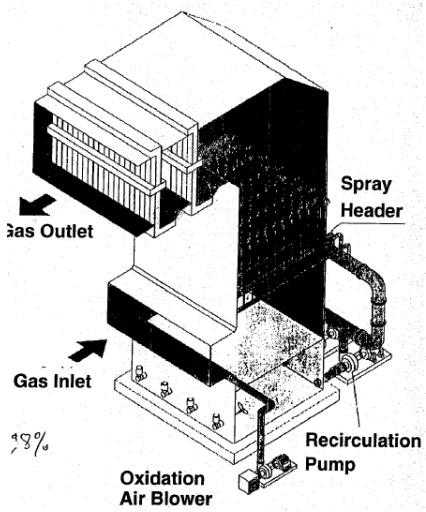
Absorber Island



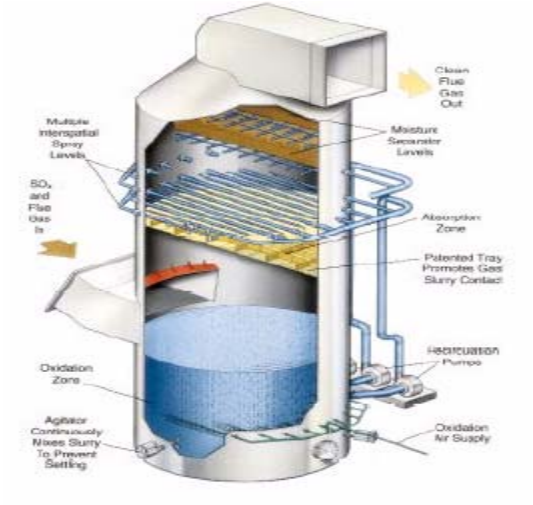
Absorber Designs



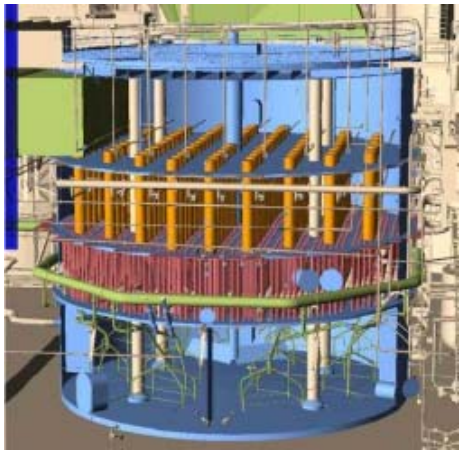
Open Spray Tower



Fountain Tower



Tray Tower



Jet Bubbling Reactor

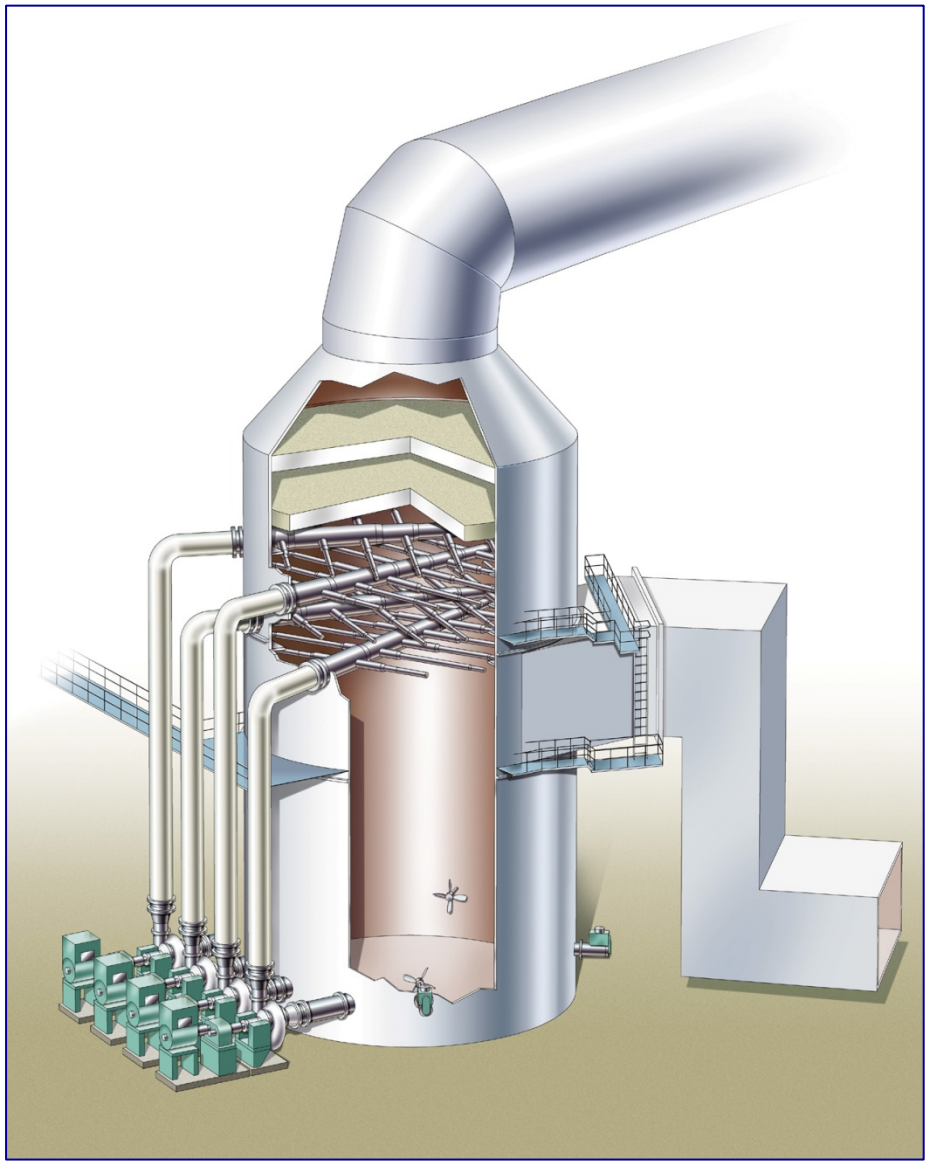
Absorber Unit Operations

Unit Operations

- Inlet – gas distribution, humidification
- Spray zone – gas/liquid contact
- Mist eliminator zone – liquid/gas separation
- Reaction tank – oxidation, dissolution, crystallization

Design Goals

- Lowest lifecycle cost
  - Capital
  - O&M
- High reliability

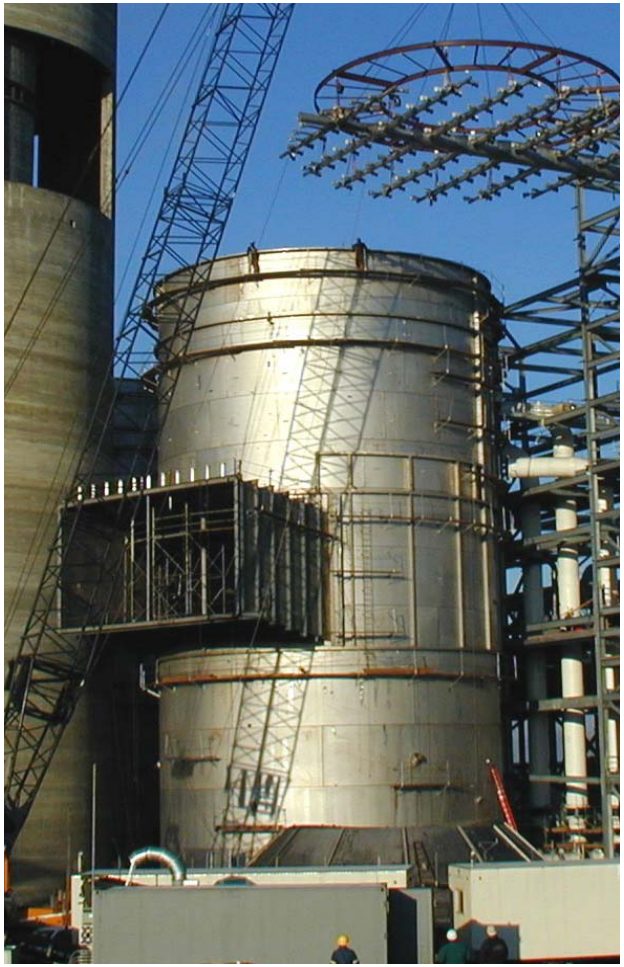


Absorber Inlet

- Highly corrosive environment
  - SO_3 condensation
  - Deposits/splash-back
- Design/construction
  - Solid 3/16” thick C-276
  - 10º slope toward absorber
  - Extends 10-15 ft. from shell
  - Internal overhead deflector and side shields
  - Test ports and emergency quench nozzles
  - Gas velocity – 3,000-3,600 ft/min

Absorber Shell

Flared-Side

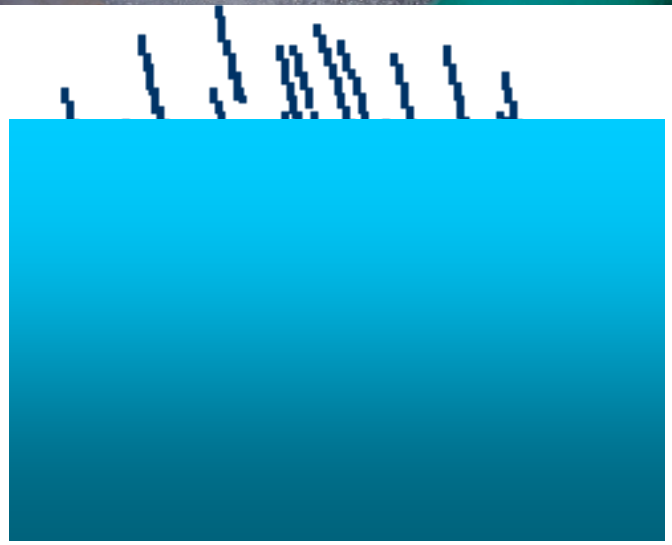


Straight-Side

Contact Zone

- Multiple spray levels with dedicated pumps allows efficient turndown
- Gas velocity – 13-14 ft/sec

- Spray flow
  - Typical afternoon thunderstorm – 1-2 in/hr
  - Spray tower – 10 ft/min



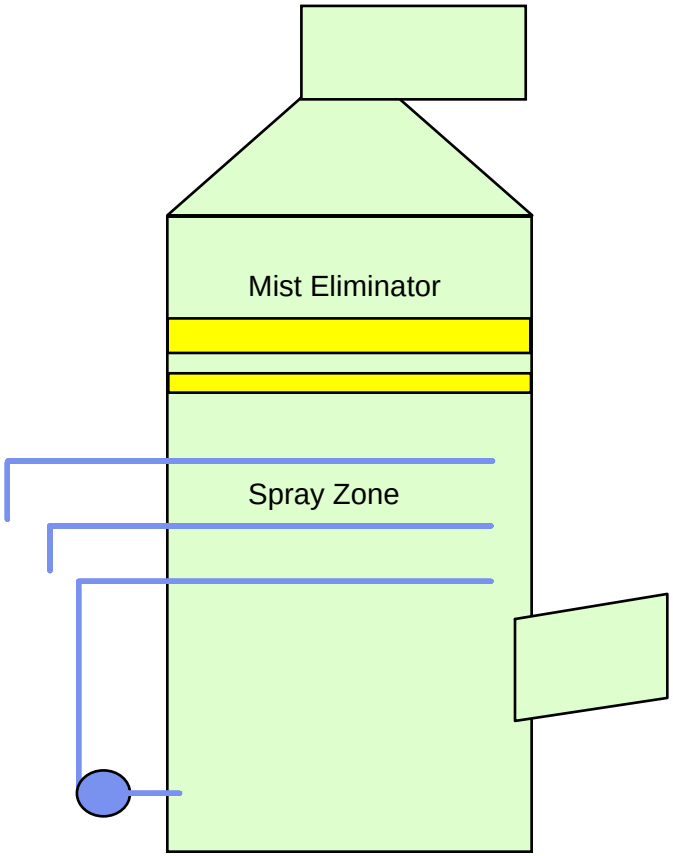
Contact Zone

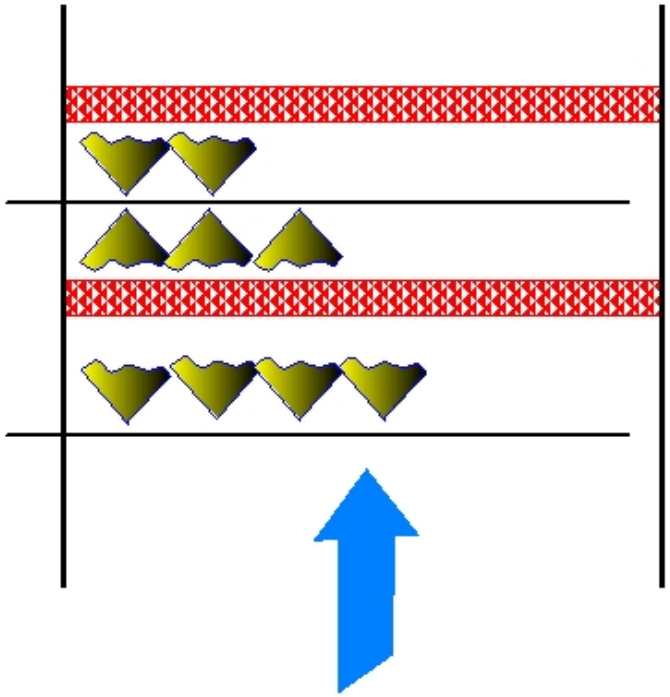
- Design Approach
  - Intimate gas/liquid contact
  - No gas sneakage
- Multiple spray stages depending on SO_2 inlet and removal efficiency
- Overall spray coverage (>200% at 3-feet) and nozzle distribution to provide even distribution and prevent gas sneakage.
- Wall rings to prevent gas sneakage near side walls.
- Pressure drop vs. pumping power trade-off

Spray Nozzles

- Multiple counter-current spray stages
- Nozzle type
  - Top stage—single orifice hollow cone
  - Lower stages—dual orifice hollow cone
- Sauter mean droplet diameter of ~2,000 micron at 8 psig
- Silicon carbide construction

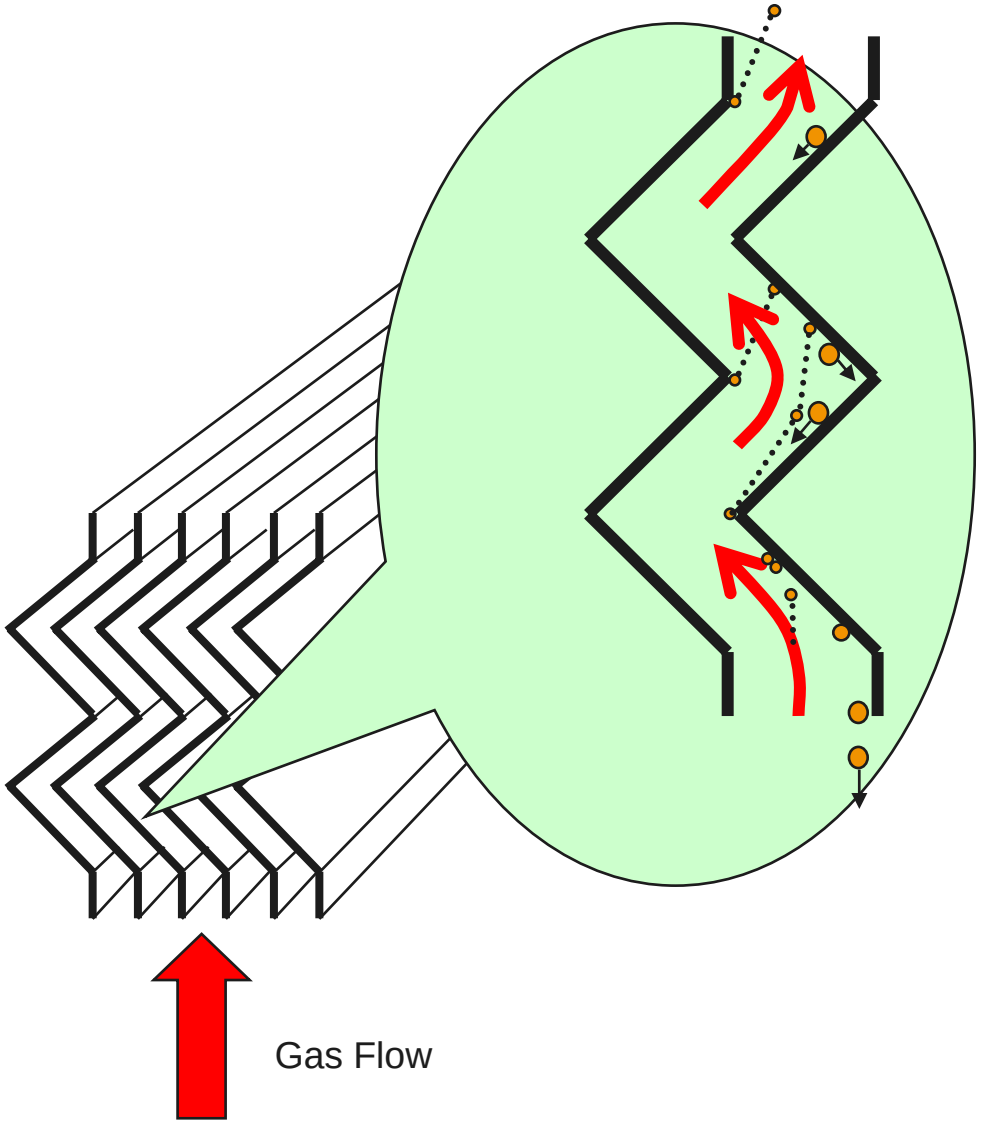
Mist Eliminator

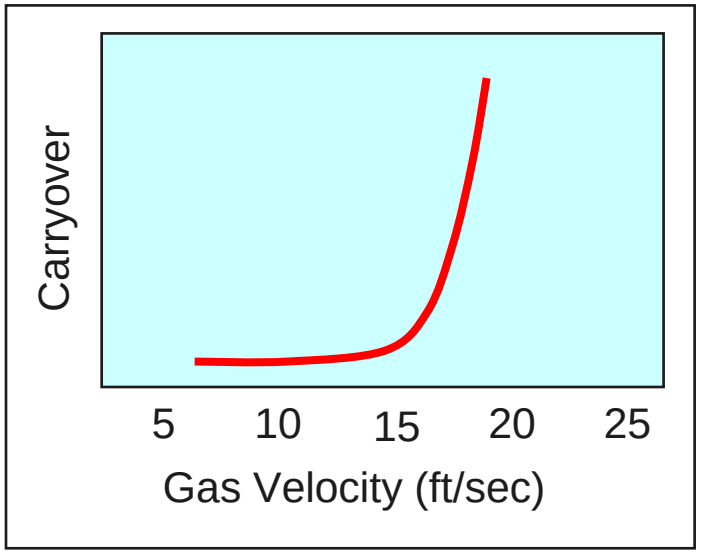




- Two stages of vertical-flow chevron vanes
- Construction
  - Polypropylene
  - Polysulfone
  - FRP
  - Alloy/stainless steel

Mist Eliminator Operation





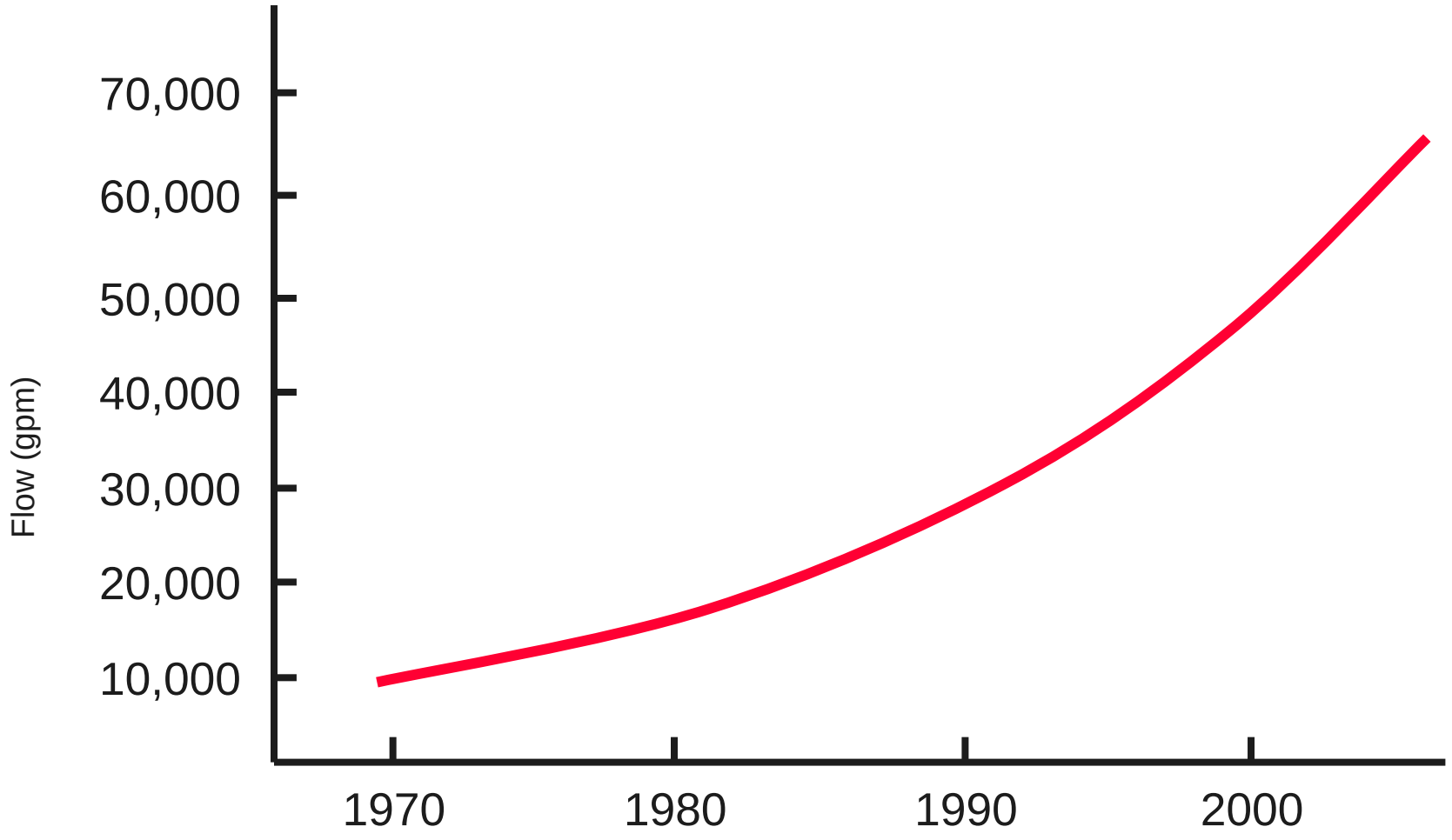
Mist Eliminator Wash System

- Fresh water wash on intermittent basis
  - First stage washed from below (1.5 gpm/ft^2) and above (0.75 gpm/ft^2)
  - Second stage washed from below (0.75 gpm/ft^2)
- Construction
  - Piping – FRP, polypropylene, alloy/SS
  - Nozzles – polypropylene, alloy/SS

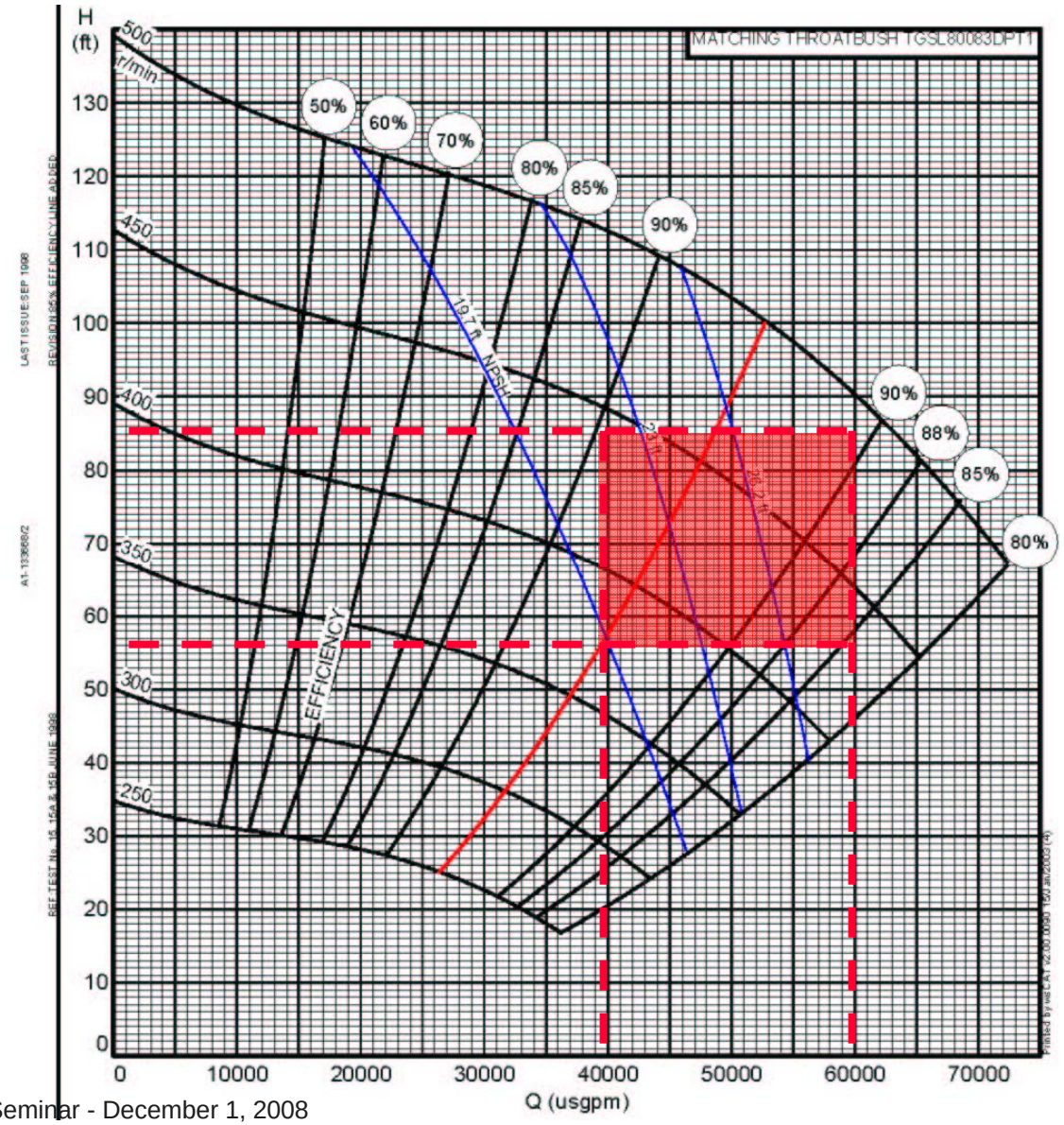
Absorber Recycle Pumps

- Typical size: 50,000-75,000 gpm at 55-85 TDH
- Pump Efficiency: 87-90+%
- 1,000-2,500 hp
- Horizontal, centrifugal
- Rubber lined casing
- Impeller
  - Hard metal
  - Rubber-covered

Spray Pump Capacity



Recycle Pump Curve



Reaction Tank

- Integral to absorber
- Functions
  - Limestone dissolution
  - Oxidation
  - Gypsum crystallization
- Design considerations
  - Solids and liquid residence time
  - Foaming/freeboard
- Side entry agitators with air lances

Materials of Construction

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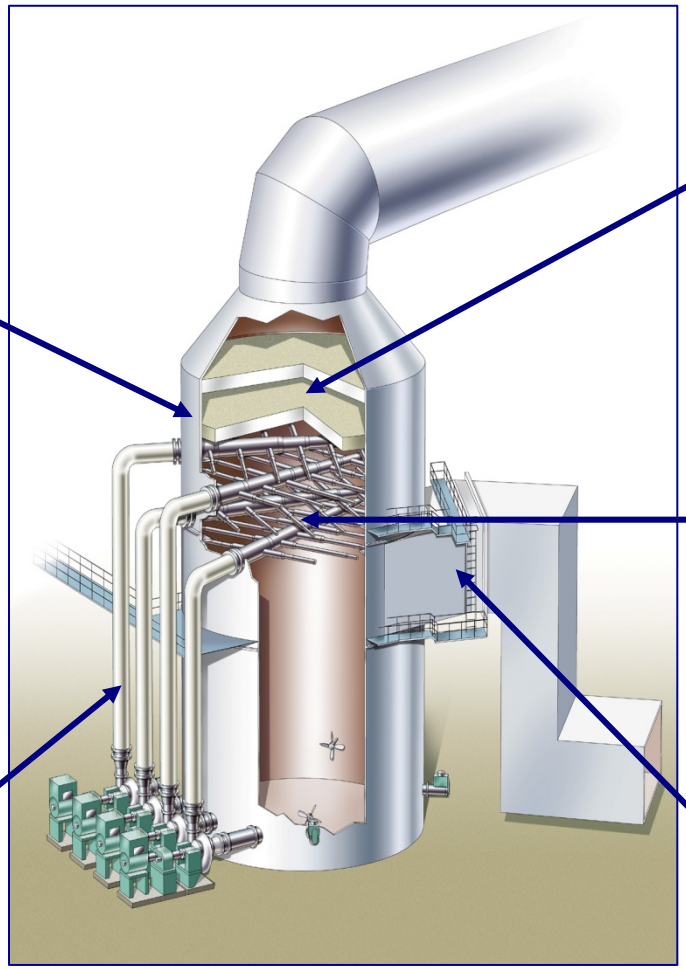
Shell
- Rubber-lined carbon steel
- Flakeglass-lined carbon steel
- Stainless steel (317LMN)
- Duplex stainless steel (2205, 255)
- Nickel-based alloy
- Roll-clad alloy
- Lined concrete (tile, polypropylene)

External Spray Piping
- FRP
- Rubber-lined carbon steel
- SS/alloy

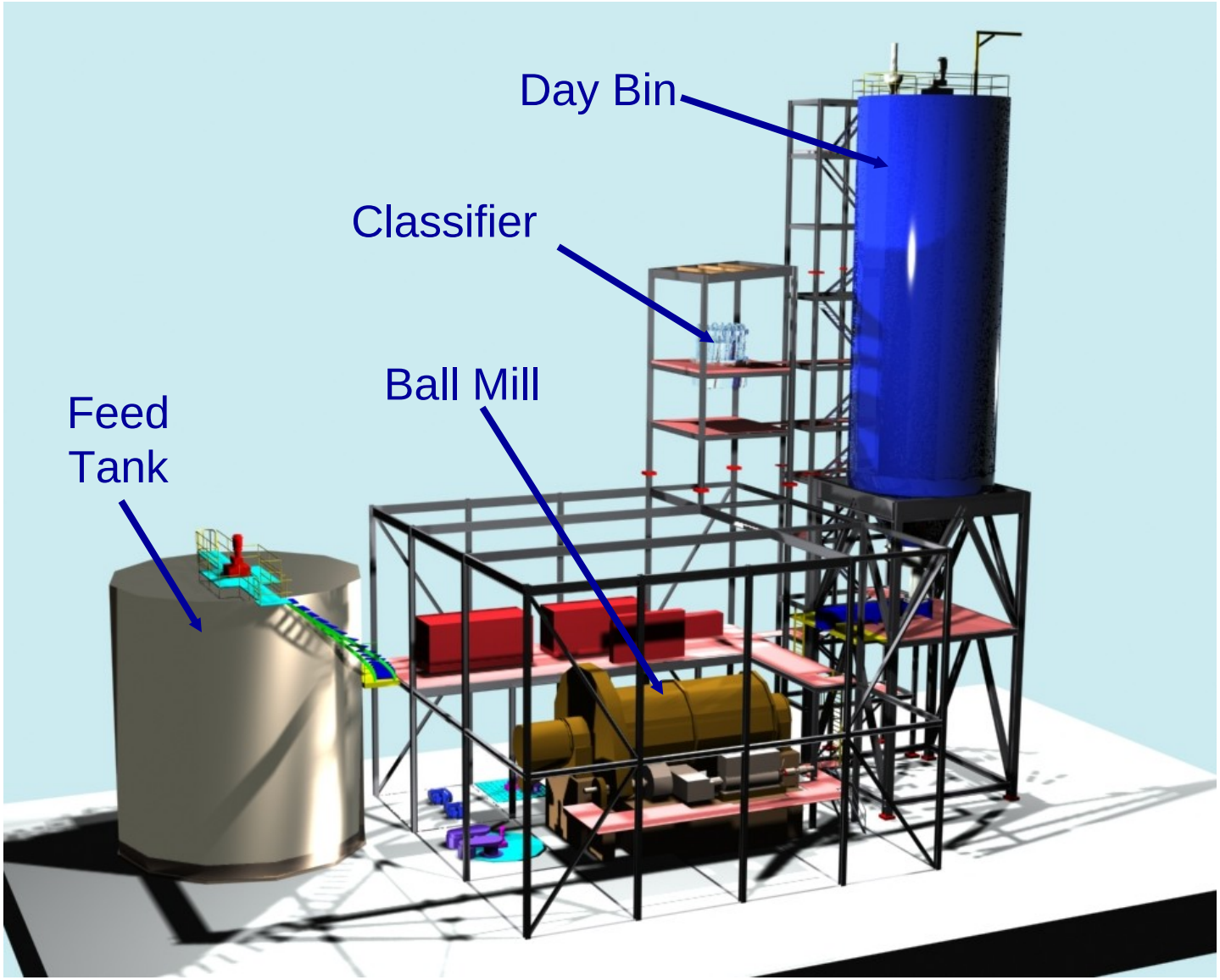


Mist Eliminators
- FRP
- Polypropylene
- Polysulfone
- SS/alloy

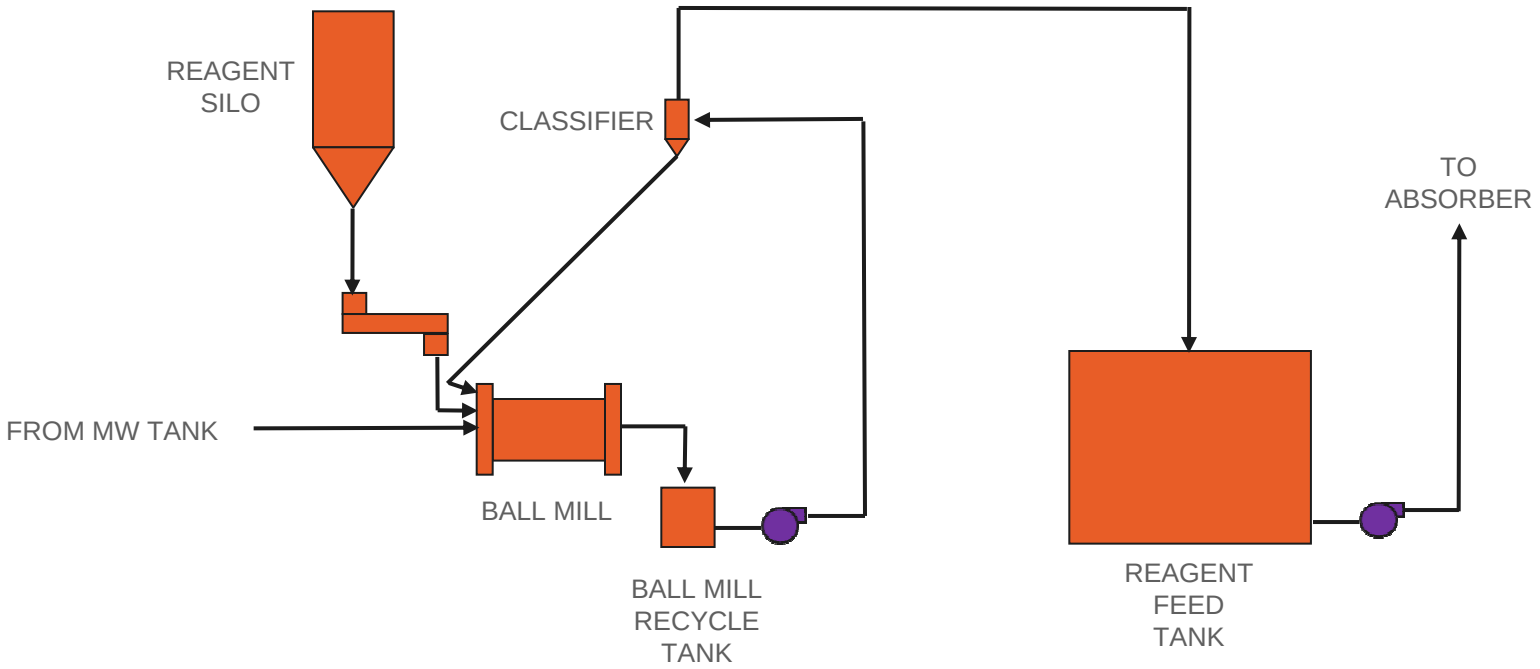
Headers
- Rubber-lined carbon steel
- FRP
- Stainless steel (317LMN)
- Duplex stainless steel (2205, 255)
- Nickel-based alloy

Inlet
- C-276

Reagent Preparation Island

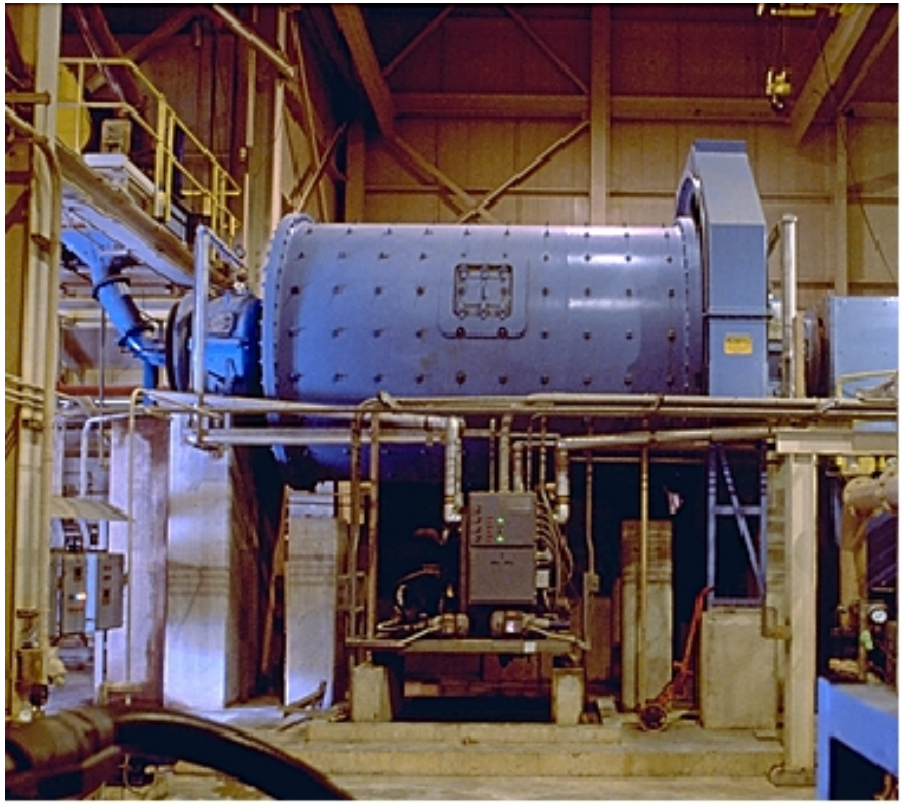


Limestone Grinding System



Limestone Preparation

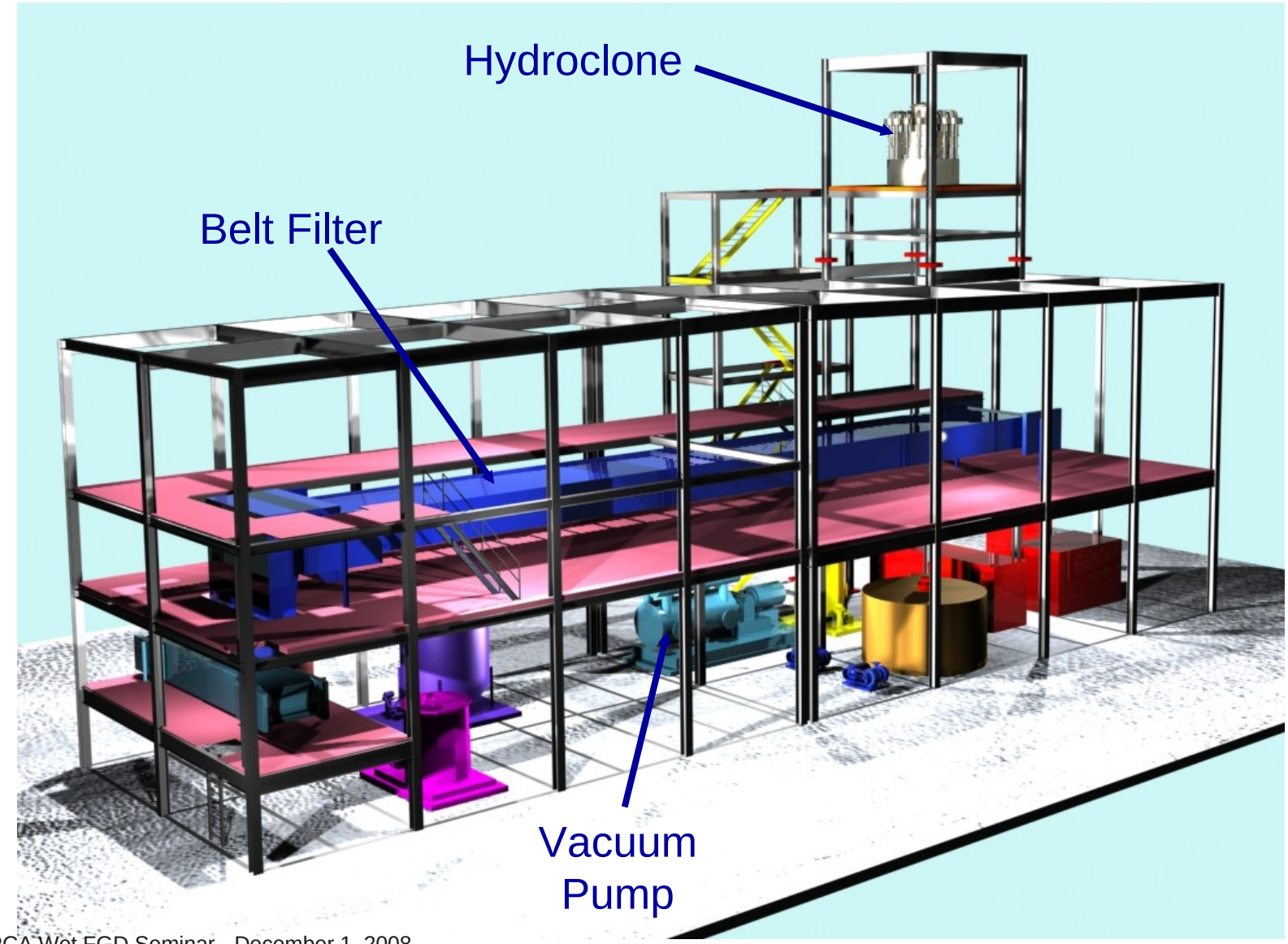
- Limestone grinding
  - Horizontal/vertical wet ball mills
  - On-site vs. off-site preparation
- Product ground to 90-95% < 44 μ; 30% solids
- Rubber-lined with hardened steel balls



Pre-Ground Limestone Injection

- Dry, pre-ground limestone feed options
  - Pneumatic injection into reaction tank below slurry level
  - Pre-slurry in small tank
- Advantages
  - Low capital cost (i.e. no ball mills, auxiliary equipment, buildings, etc.)
  - Less equipment to maintain
- Disadvantages
  - Higher delivered cost
- Lifecycle cost evaluation on case-by-case basis

Dewatering Island



Primary Dewatering

- Initial solid/liquid separation step
  - Feed: 15-20% TSS
  - Underflow: 50-55% TSS
  - Overflow: 3-5% TSS
- Overflow enriched with $CaCO_3$ due to particle size difference; improved reagent utilization
- Steel casing with rubber, urethane, and ceramic internals

Secondary Dewatering

- Horizontal belt filter
  - 8-10% moisture in gypsum
  - Optimal for cake washing
- Rotary drum filter
  - 10-15% moisture
  - Smaller footprint
- Other options
  - Gypsum stacking
  - Centrifuge
  - Thickener

Wallboard Gypsum

- Typical specification:
  - >95% $CaSO_4 \cdot 2H_2O$
  - <0.5–1.0% $CaSO_3 \cdot ½H_2O$
  - <100 ppm Cl
  - <10% moisture
  - pH 6–8
  - 30–40µ MMD
- Requires:
  - High purity limestone (95–96%)
  - High efficiency ESP/FF
  - 99+% oxidation
  - Belt filter
  - Cake washing

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Limestone Delivery/Storage

- Truck, rail, or barge delivery
- ¾” x 0” (20 x 0 mm) crushed limestone
- Outdoor long-term storage feasible in most areas
- Indoor/covered storage in harsh/wet climates

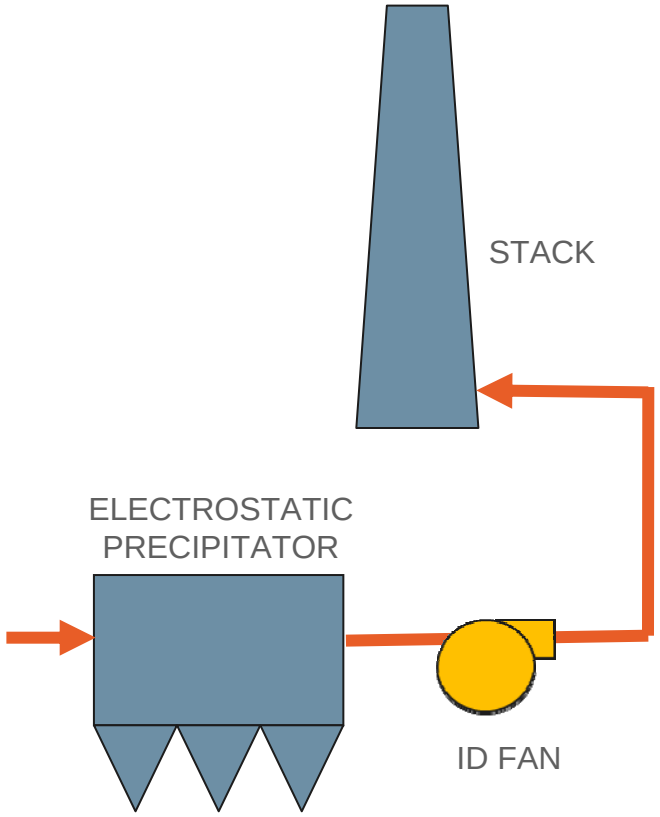
Limestone Silo

- Provide buffer between limestone pile and ball mill operation
- 16-24 hr capacity
- Carbon steel construction with polymer or stainless steel hopper lining
- Vibrating bottom/mechanical activation
- Vent filter for fugitive dust control

Gypsum Storage/Handling

- Covered storage options
  - Direct discharge to bunker/ manual reclaim
  - Convey to dome/manual reclaim
  - Convey to building or silo/ automated reclaim
- Open pile
  - Feasible
  - Possible issues: moisture, fugitive dust, leaching
- Selection depends on:
  - On-site storage requirement
  - Gypsum contract

Fan Arrangement – Retrofit



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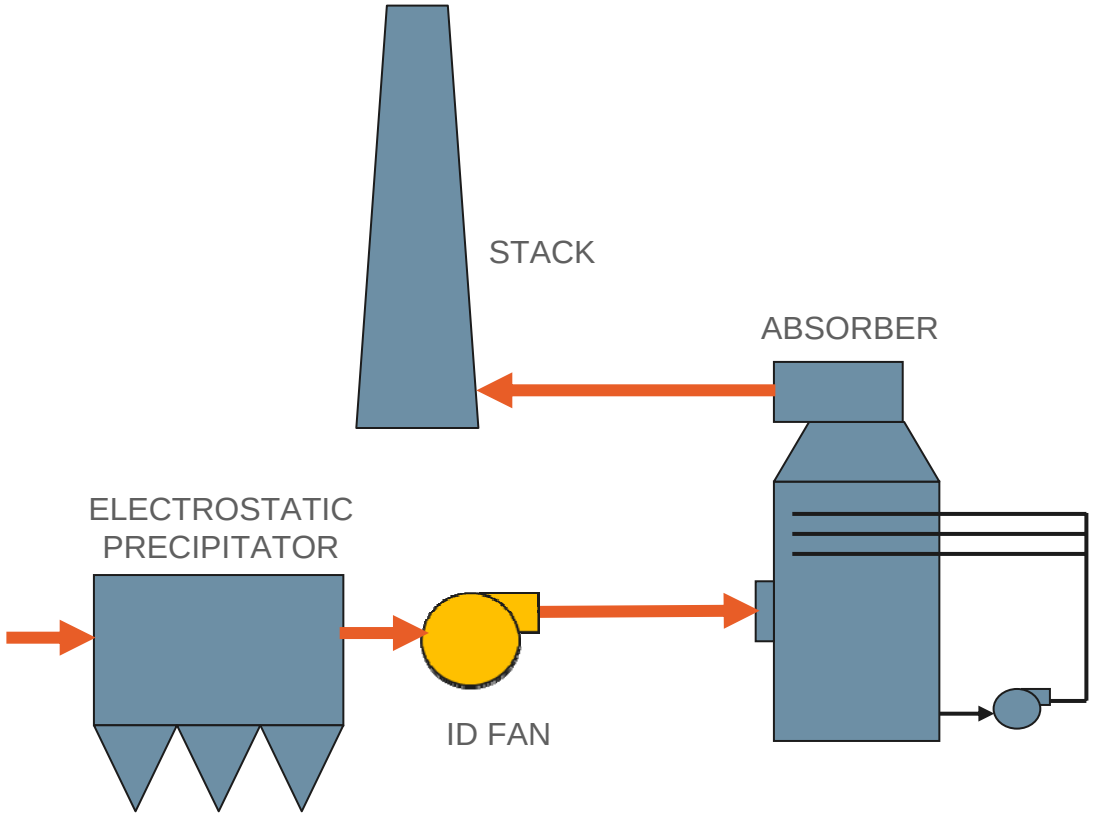
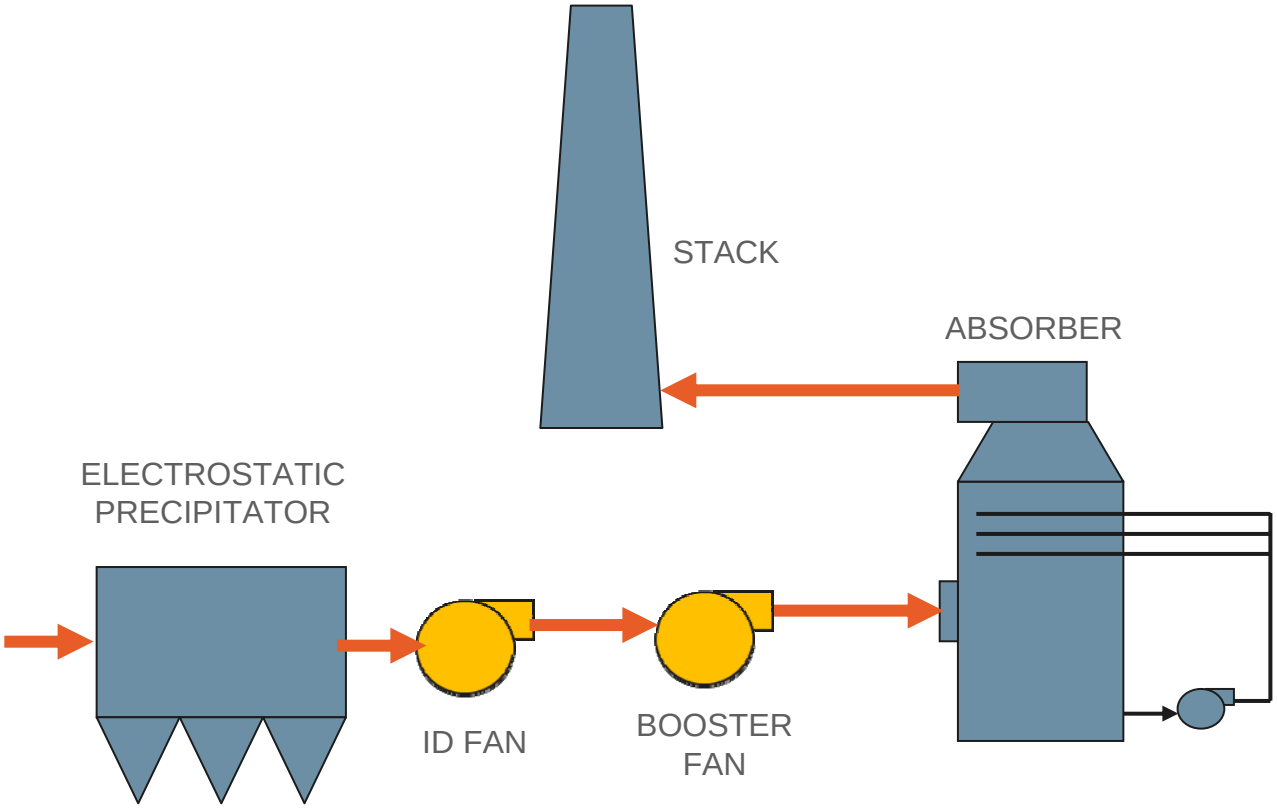
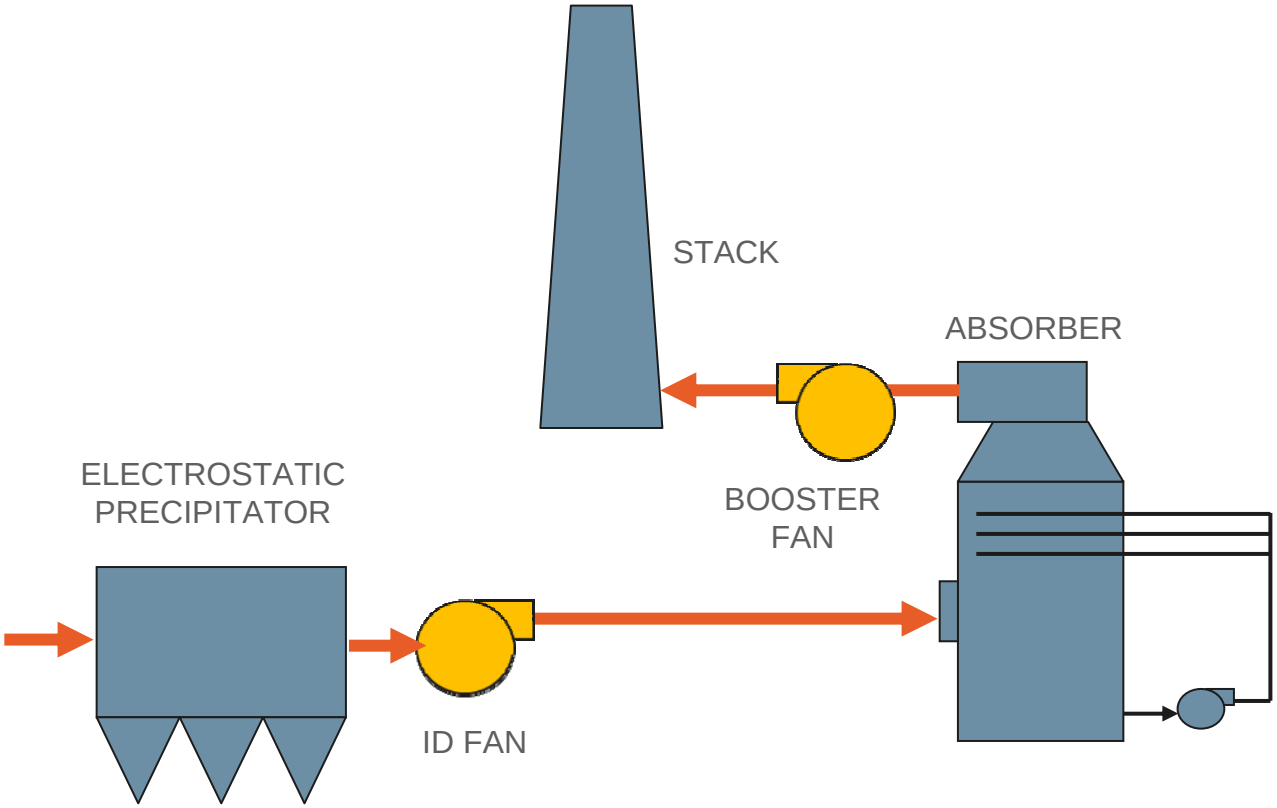


Fan Arrangement – Retrofit



Fan Arrangement – Retrofit



Wastewater Treatment

- Purge stream required to control chlorides/inert solid for wallboard gypsum
- Purge stream treatment strategy is site-specific; depends on:
  - Discharge limits
  - Receiving body
  - FGD process design
  - Fuel, limestone, make-up water
- Treatment options:
  - Direct discharge
  - Volume reduction (evaporation,…)
  - Physical/chemical treatment
    - Suspended solids
    - pH adjustment
    - Heavy metals removal
    - COD removal

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WFGD Controls

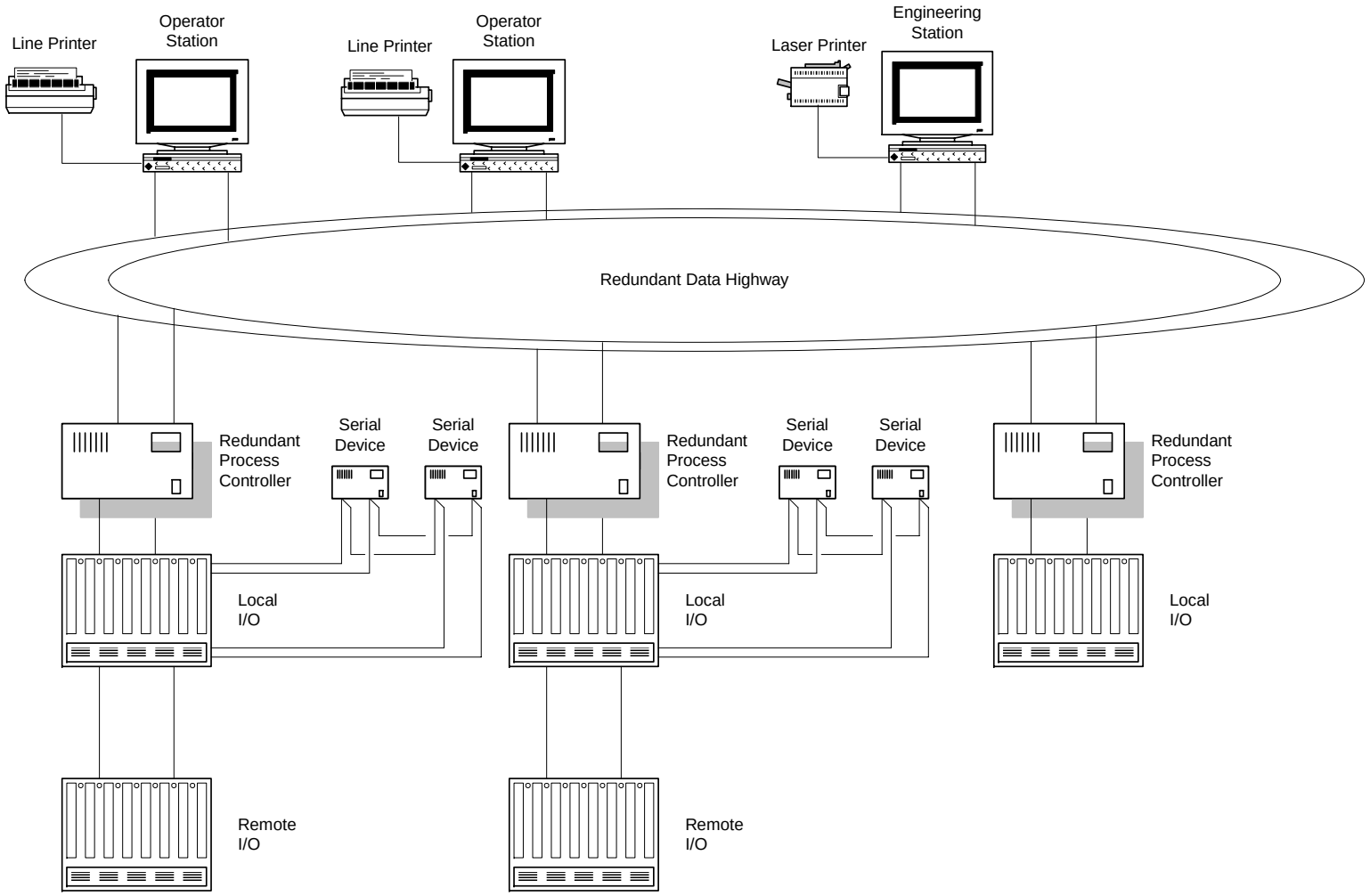
- Distributed Control Systems
  - Overview
  - Redundancy
- Primary WFGD Control Loops & Instrumentation
  - Absorber Area
  - Flue Gas System

WFGD Control Systems

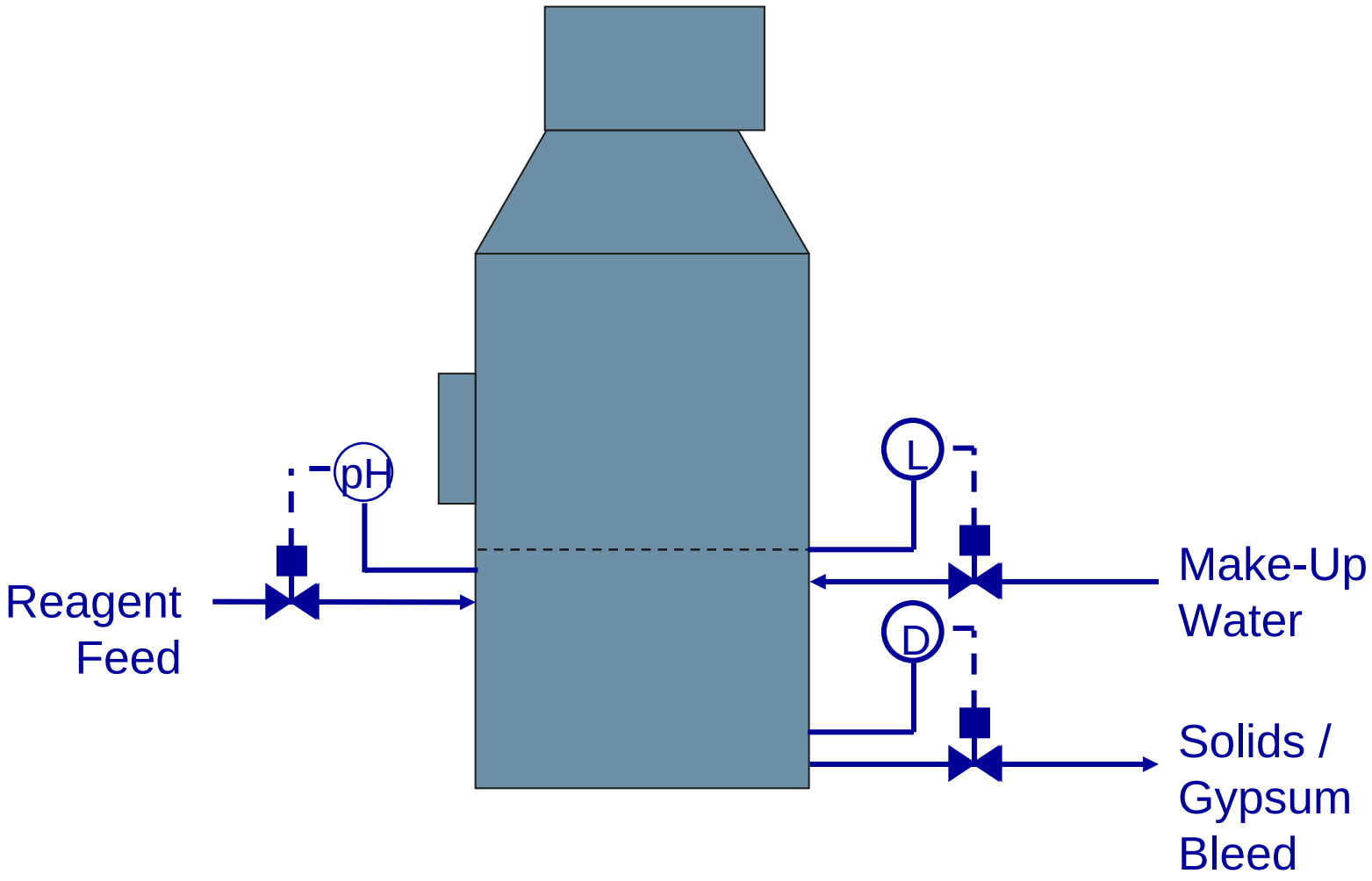
- Distributed Control Systems (DCS)
  - Control and automation of WFGD processes and components
  - Interface with remaining power plant controls
  - Monitor key process parameters
  - Process trends, reports, historical data logging
- Local Control Panels (LCP)
- Programmable Logic Controllers (PLC)
- Main FGD Control Area
  - Dedicated WFGD Control Station
  - Centralized WFGD Control with Boiler/Power Plant

Distributed Control System

DCS CONFIGURATION DIAGRAM

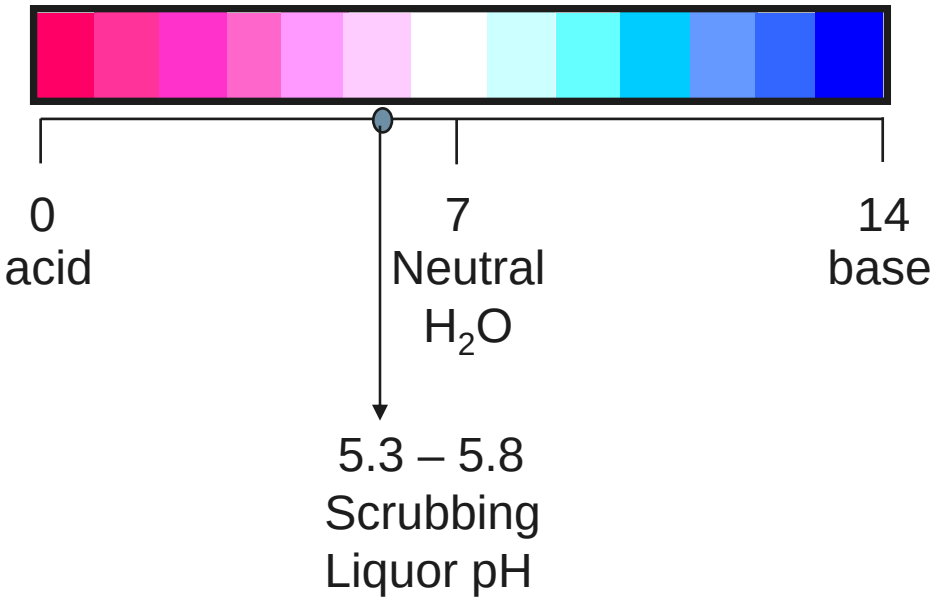


Major Control Loops - Absorber



pH / Reagent Feed Control

- Scrubbing Liquor pH
  - Most important process variable to be controlled in WFGD → continuous, in-line monitoring, daily lab verification
  - Indication of the amount of $CaCO_3$ in scrubbing solution
  - Scrubbing liquor below desired range → lower SO_2 removal efficiency
  - Scrubber liquor above desired range → higher SO_2 removal efficiency, excess $CaCO_3$ and reduced gypsum byproduct purity



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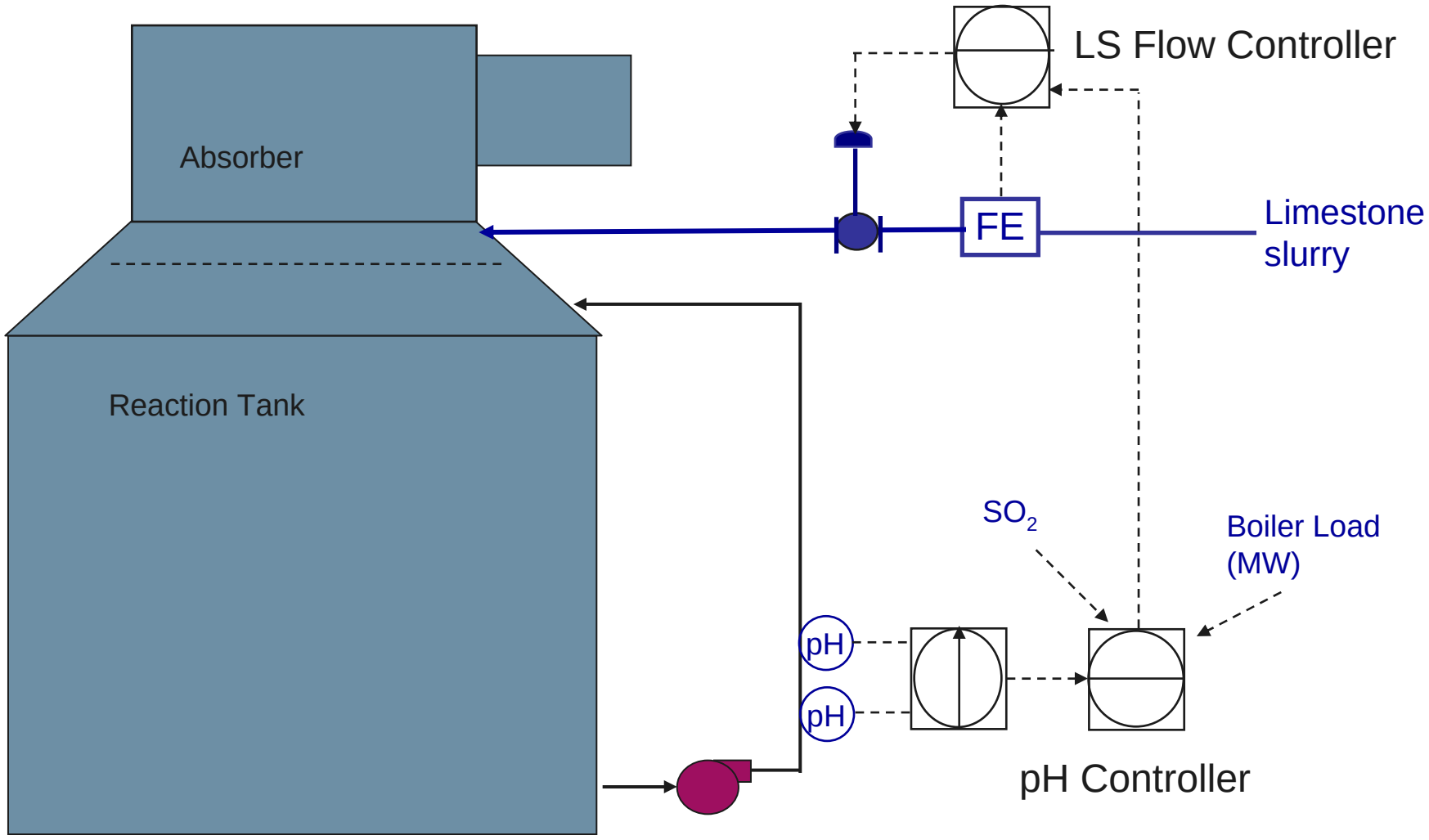
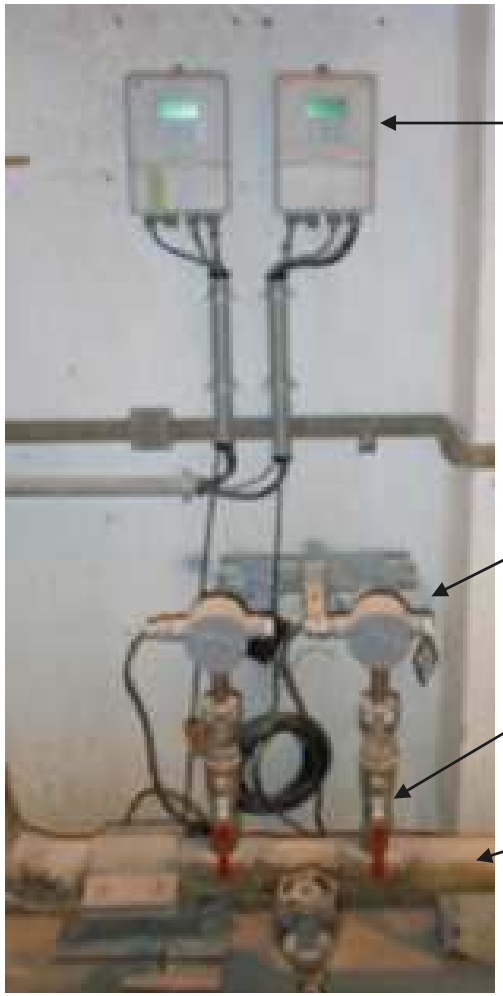
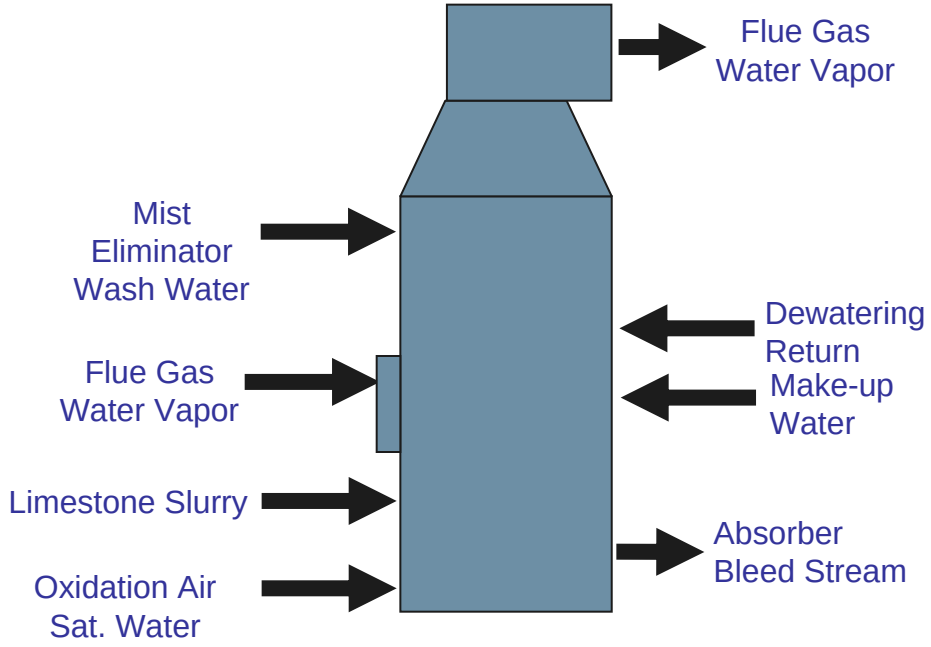


pH Instrumentation

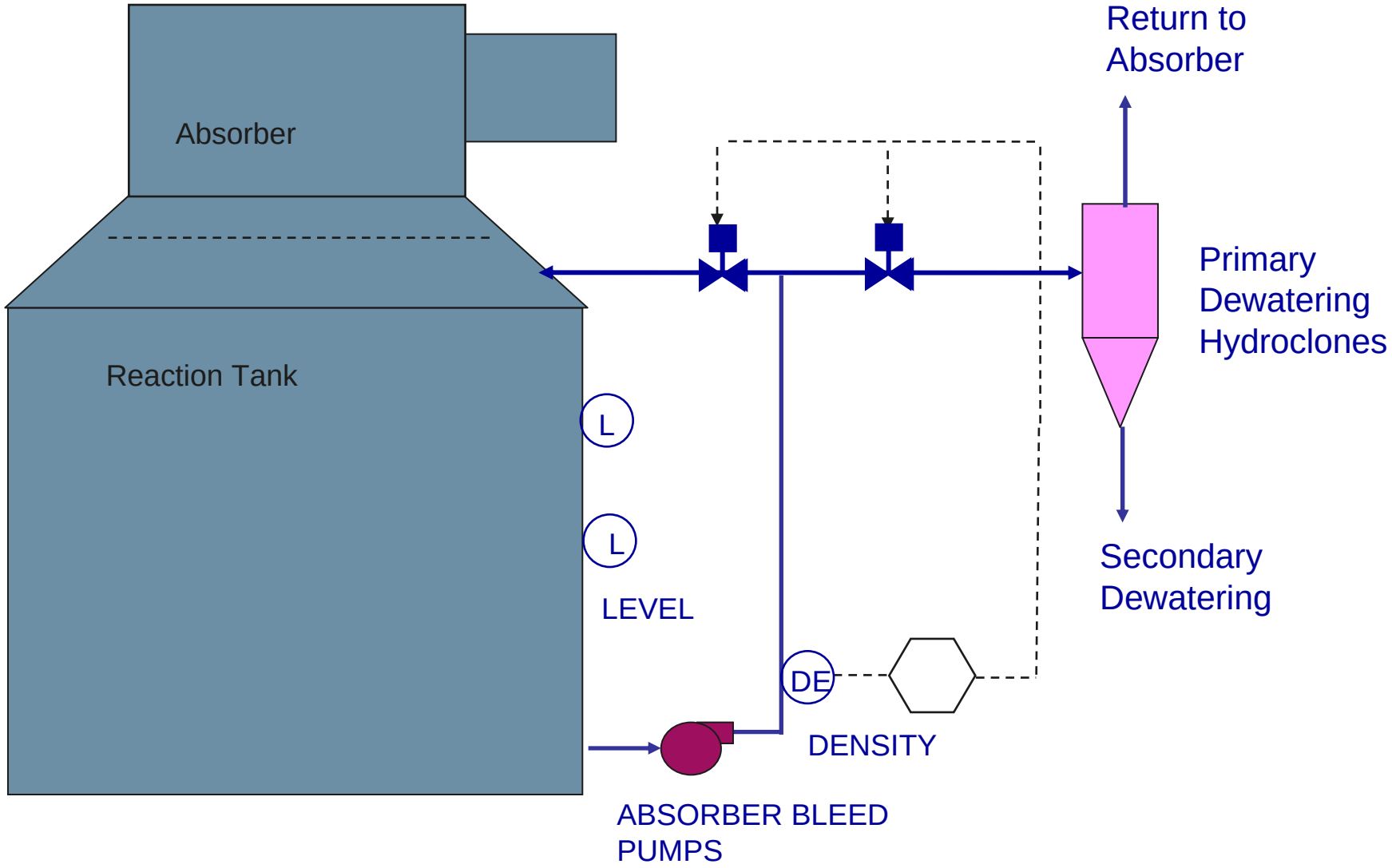


Gypsum Bleed / Solids Control

- Scrubber Slurry Solids
  - Important WFGD process variable, verified daily with laboratory samples
  - Scrubber slurry solids: gypsum, limestone, flyash, inerts
  - Numerous inputs affecting water balance and solids concentration
  - Control solids concentration within narrow range: 14-16 wt.%
- Solids Control
  - Solids too low: potential for gypsum scaling
  - Solids too high: increased potential for wear of equipment
  - Equipment sizing

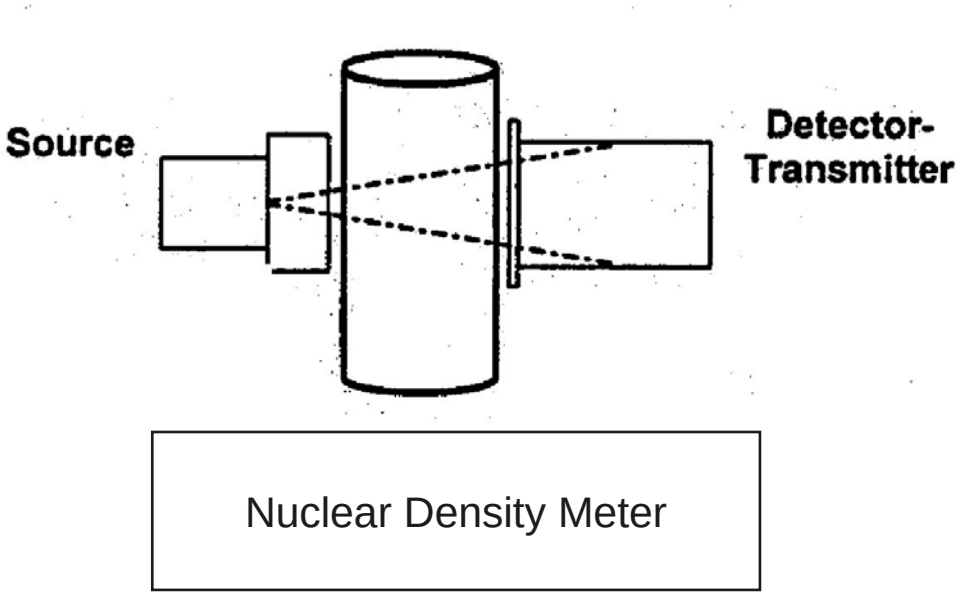


Gypsum Solids / Density Control



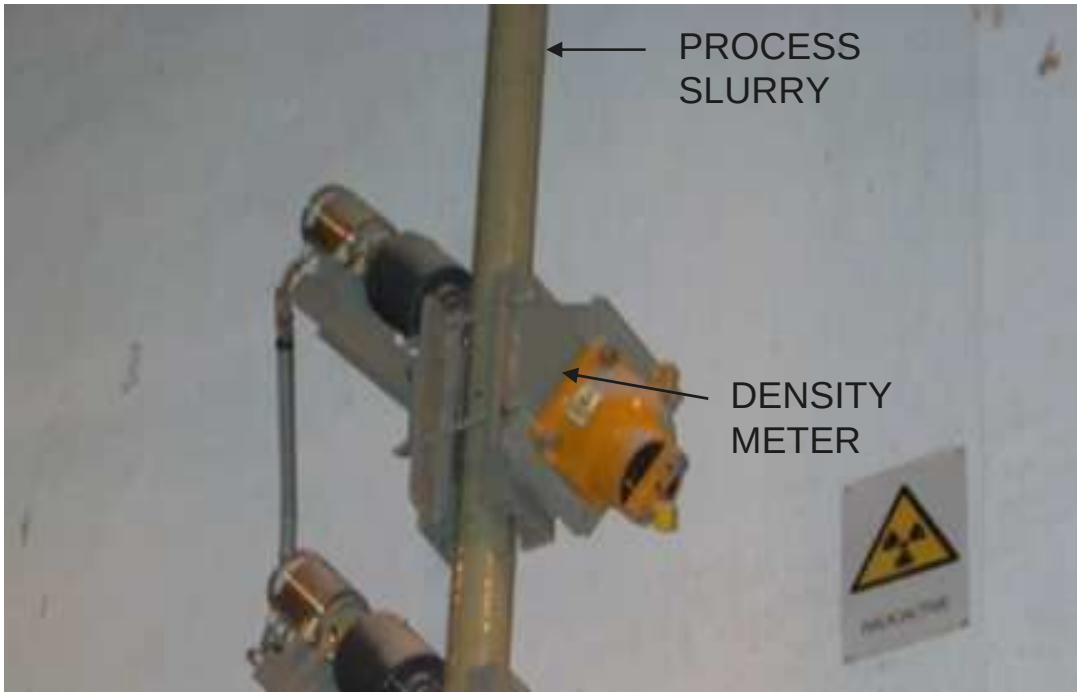
Density Measurement

- Nuclear Density Meters
  - Source emits gamma radiation through process
  - Detector measures energy of radiation
  - Capable of detecting process variations within desired narrow range
  - Safe
  - Accurate
  - Simple calibration
  - Verify with laboratory analyses

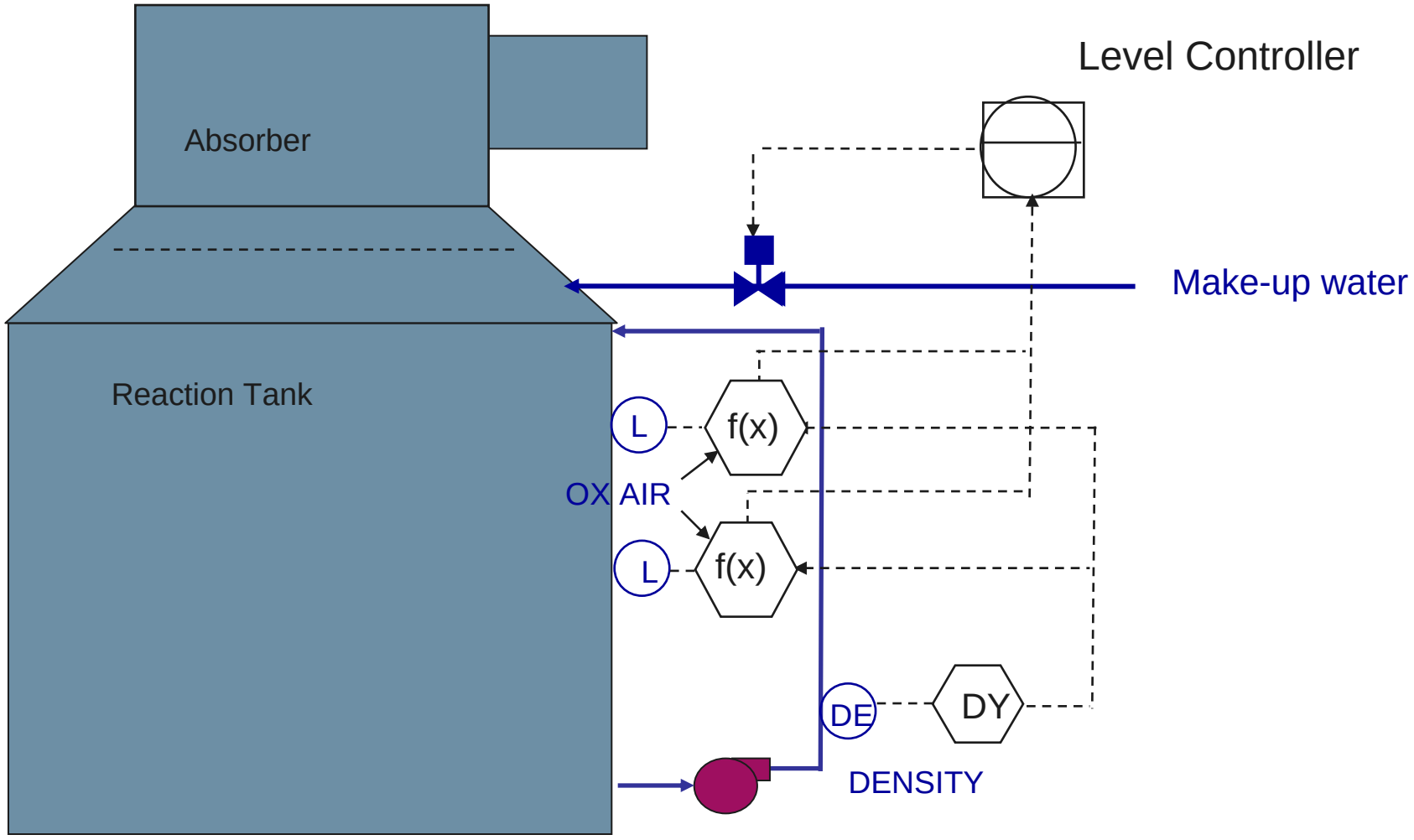


Nuclear Density Meter

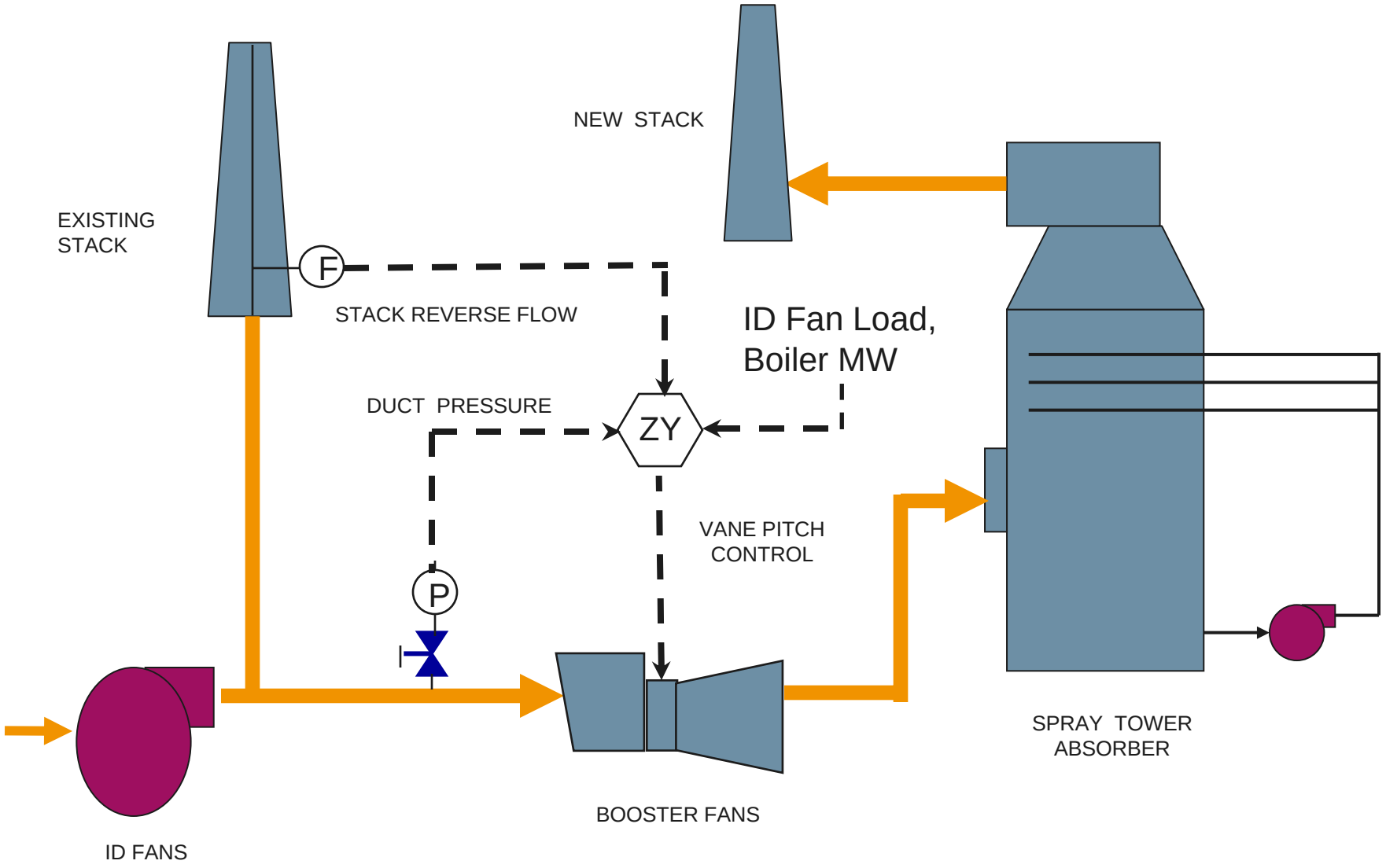
Density Instrumentation



Level / Make-Up Water Control



Booster Fan Control



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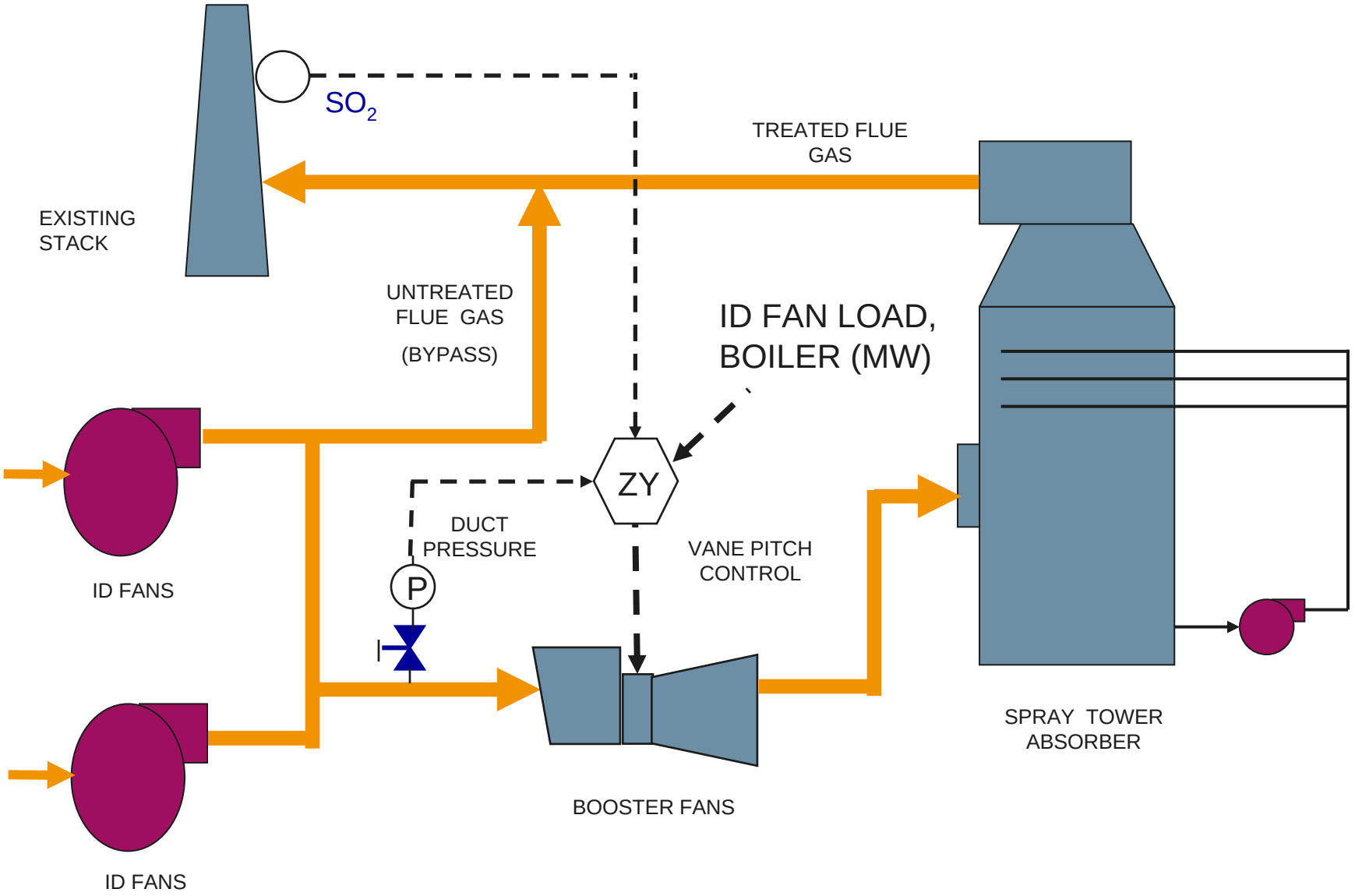
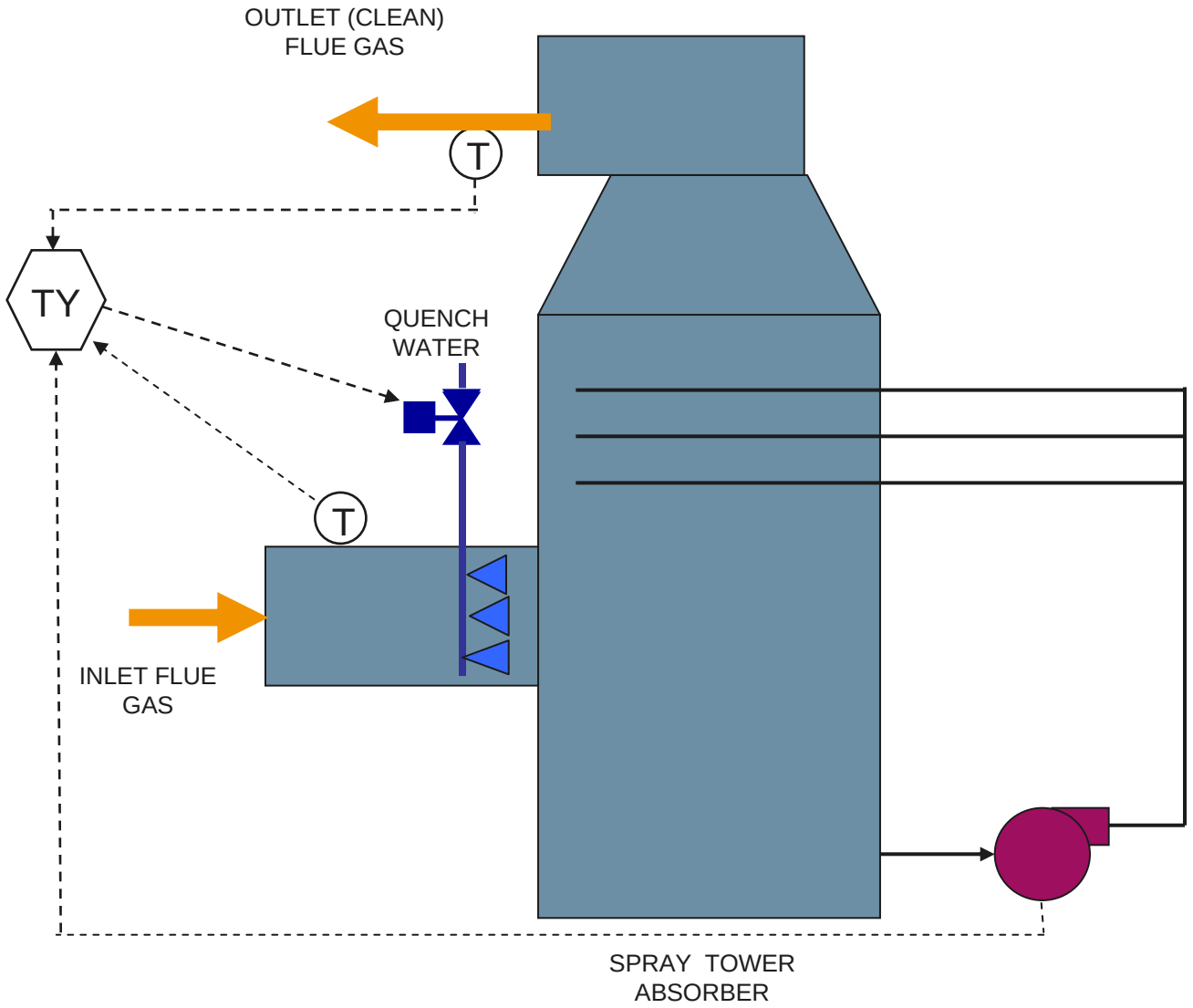


Emergency Quench



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WFGD Operations Staff

- O&M staffing varies; depends on:
  - Owner staffing philosophy/ practices
  - Plant layout/design
  - Reagent/byproduct
  - Labor bargaining agreements
  - Other equipment at plant

O&M Staff for 2 x 700 MW WFGD

Position Description	No.	Coverage
FGD Supervisor	1	1 shift, 5 days/week
FGD Operator	1	3 shifts, 7 days/week
FGD Mechanic	1	1 shift, 5 days/week
FGD Computer Tech	1	1 shift, 5days/week
FGD Specialist	1	1 shift, 5 days/week
FGD Material Handling	1	3 shifts, 7 days/week

Lifecycle Cost Comparison

		High Sulfur	Low Sulfur
Total Plant Capital Cost	$	150,000,000	120,000,000
	$/kW	250	200
Plant Capacity (per unit)	MWe	600	600
No. Units		1	1
Plant Capacity Factor	%	85	85
Equivalent Full-Load Hour	hr	7,446	7,446
Escalation Rate	%	3.0	3.0
NPV Discount Rate	%	10.0	10.0
SO2 Removal	%	98	98
SO2 Production Rate	lb/hr	45,000	12,000
	lb/MMBtu	7.50	2.00
ID Fan Flue Gas Flow	acfm	2,100,000	2,220,000

Lifecycle Cost Comparison

		High Sulfur	Low Sulfur
No. O&M Personnel/Shift		5	5
O&M Labor Rate	$/hr	50.00	50.00
AQCS Power	kW	9,000	4,500
Fan Power Consumption	kW	2,464	1,628
Total Power	kW	11,464	6,128
Power Cost	$/kW-hr	0.03	0.03
Limestone Consumption	lb/hr	74,709	19,922
Limestone Cost	$/ton	20.00	20.00
Gypsum Production	lb/hr	138,618	36,965
Gypsum Price	$/ton	(5.00)	(5.00)
Repair/Maintenance	% of TPC	1.5	1.5

Lifecycle Cost Comparison

Technology		High Sulfur	Low Sulfur
O&M Labor	$/yr	2,190,000	2,190,000
Auxiliary Power	$/yr	2,560,776	1,368,838
Limestone	$/yr	5,562,823	1,483,420
WWTS Reagents	$/yr	1,500,000	500,000
Gypsum	$/yr	(2,580,382)	(688,102)
Repair/Maintenance	$/yr	2,250,000	1,800,000
Total	$/yr	11,483,218	6,654,156
	$/MW-hr	2.57	1.49
Total Plant Capital Cost	$	150,000,000	120,000,000
O&M Cost (25-Yr NPV)	$	138,240,000	69,540,000
Lifecycle Cost	$	288,240,000	189,540,000

Summary

- WFGD system design is mature; operation is routine
- Major process islands
  - Absorber
  - Reagent
  - Dewatering
- Key balance of plant equipment
  - Flue gas handling
  - Material handling
  - Wastewater treatment
  - Electrical system

Questions?

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