

REINHOLD ENVIRONMENTAL Ltd.



2011 APC Round Table & Expo Presentation

July 11-12, 2011, in Cleveland, OH / Hosted by FirstEnergy

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State of the Art DFGD: Operating Experience and Best Practices

2011 APC Round Table

Phil Rader & Steve Francis

Cleveland, OH – July 11, 2011

POWER

ALSTOM

Introduction

DFGD Overview

SDA Technology

NID / CDS Technology

Fabric Filter Technology

Summary

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Business Sales Manager

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Product Engineering Manager

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Knoxville, TN



Introduction

DFGD Overview

SDA Technology

NID / CDS Technology

Fabric Filter Technology

Summary

- Nearly 25,000 MW operating on US coal-fired utility boilers
- First units commissioned in late 1970s
- Technology options:
 - SDA (Spray Dryer)
 - NID / CDS (Circulating Dryer)
- High efficiency capture of sulfur dioxide (SO_2), sulfur trioxide (SO_3), HAPS, and particulate
- Traditionally employed on low sulfur western coals
- New designs expanding applicability to high sulfur coals



Introduction

DFGD Overview

SDA Technology

NID / CDS Technology

Fabric Filter Technology

Summary

- Over 20,000 MW operating on US coal-fired utility boilers
- Technology options:
 - Rotary atomizers
 - Dual-fluid nozzles
- Rotary atomizers predominant in US power industry



Rotary Atomizer SDA



Dual-Fluid Nozzle SDA

Key Process Steps

- Atomize slurry droplets
- Absorb acid gases
- Dry particles
- Collect byproduct
- Recycle byproduct



Slaking Reaction

- $\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{Heat}$

Absorption / Drying Reactions

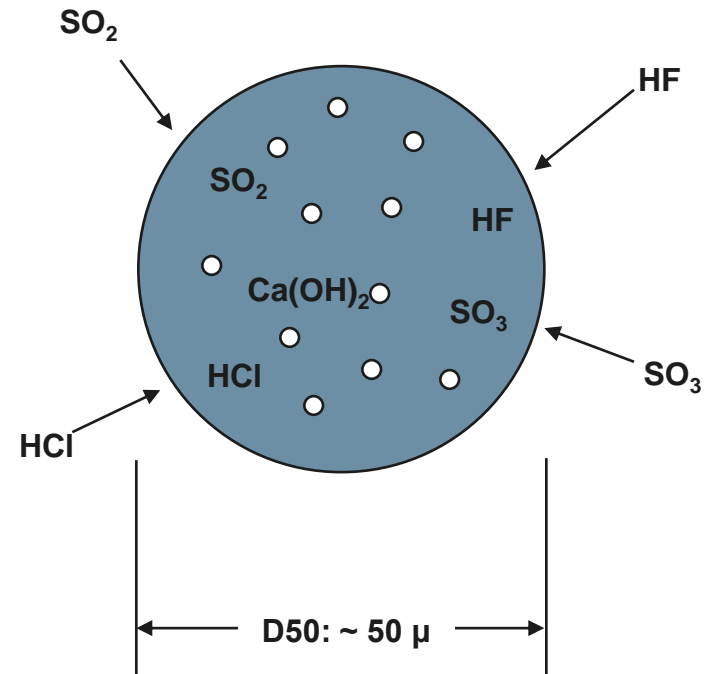
- $\text{SO}_2(\text{g}) + \text{Ca(OH)}_2 \rightarrow \text{CaSO}_3 \cdot \frac{1}{2} \text{H}_2\text{O}(\text{s}) + \frac{1}{2} \text{H}_2\text{O}(\text{g})$
 - $\text{CaSO}_3 \cdot \frac{1}{2} \text{H}_2\text{O}(\text{s}) + \frac{1}{2} \text{O}_2 + 1.5 \text{H}_2\text{O}(\text{g}) \rightarrow \text{CaSO}_4 \cdot 2 \text{H}_2\text{O}(\text{s})$
- $\text{SO}_3(\text{g}) + \text{Ca(OH)}_2 + \text{H}_2\text{O} \rightarrow \text{CaSO}_4 \cdot 2 \text{H}_2\text{O}(\text{s})$
- $2 \text{HCl}(\text{g}) + \text{Ca(OH)}_2 \rightarrow \text{CaCl}_2 \cdot 2 \text{H}_2\text{O}(\text{s})$
- $2 \text{HF}(\text{g}) + \text{Ca(OH)}_2 \rightarrow \text{CaF}_2 + 2 \text{H}_2\text{O}(\text{s})$



Rotary Atomizer



Dual-Fluid Nozzle

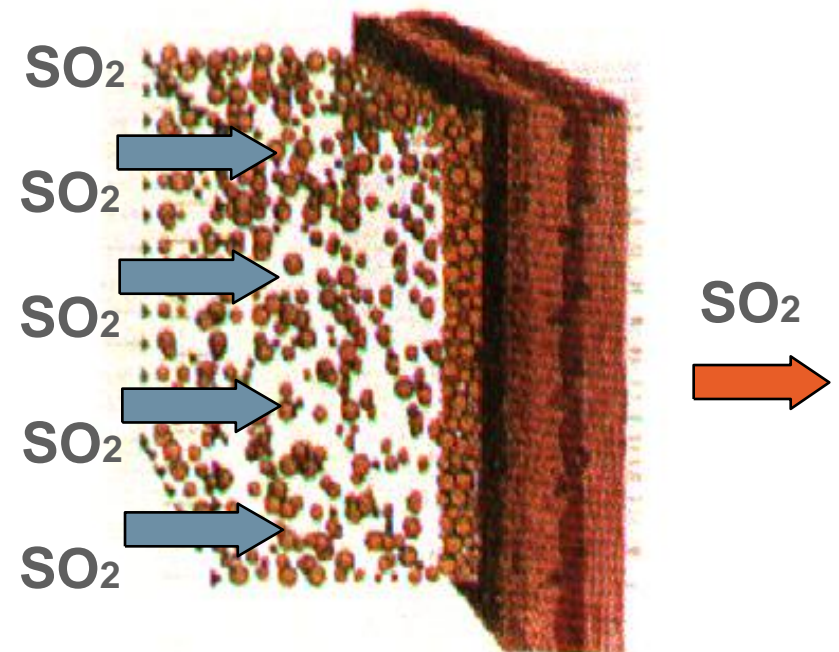


- Second Stage Reaction

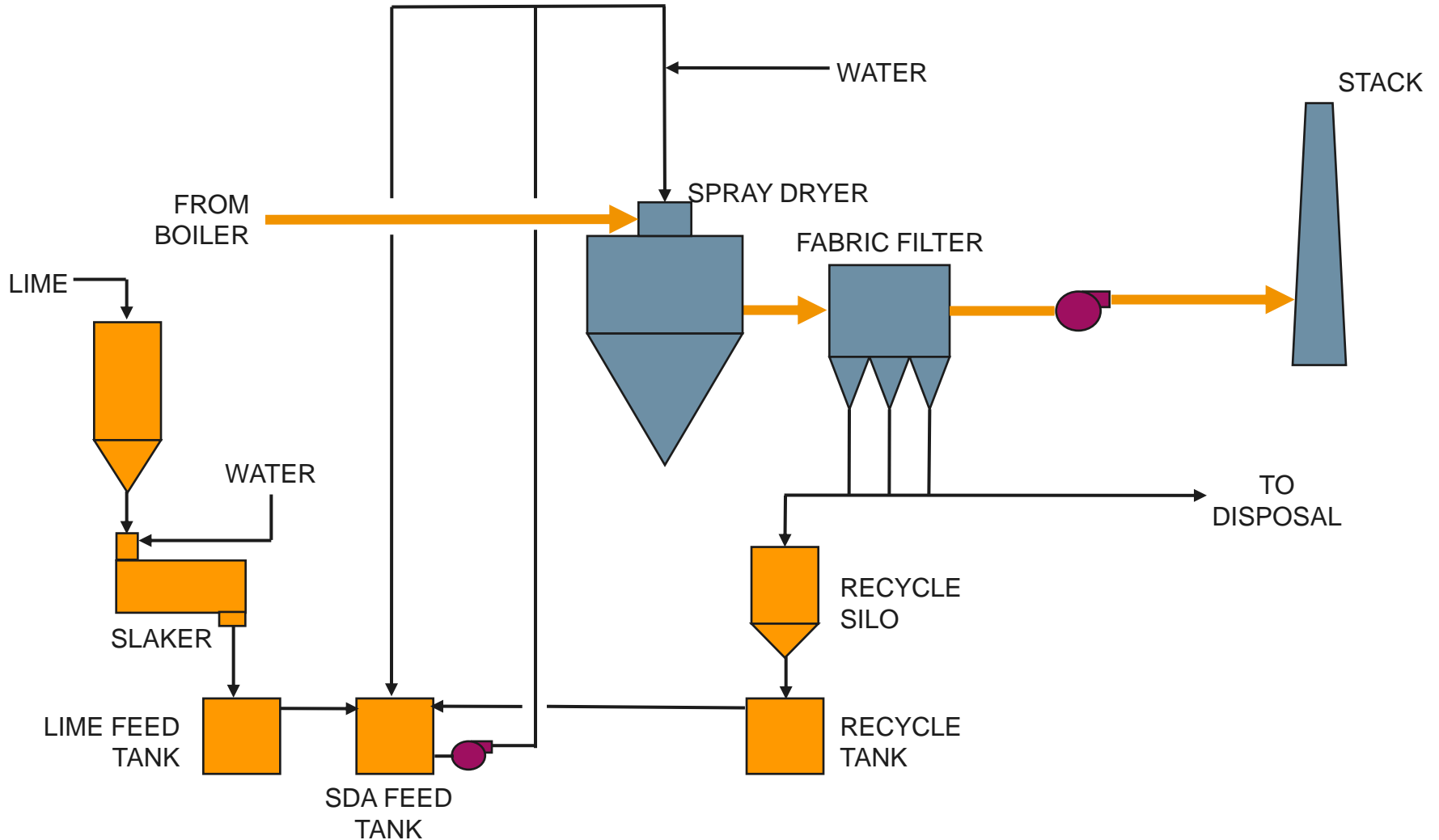
- SO_2
- SO_3
- HCl / HF
- Hg
- Other trace elements

- Collection

- Fly ash
- Carbon



DFGD Process Flow Diagram



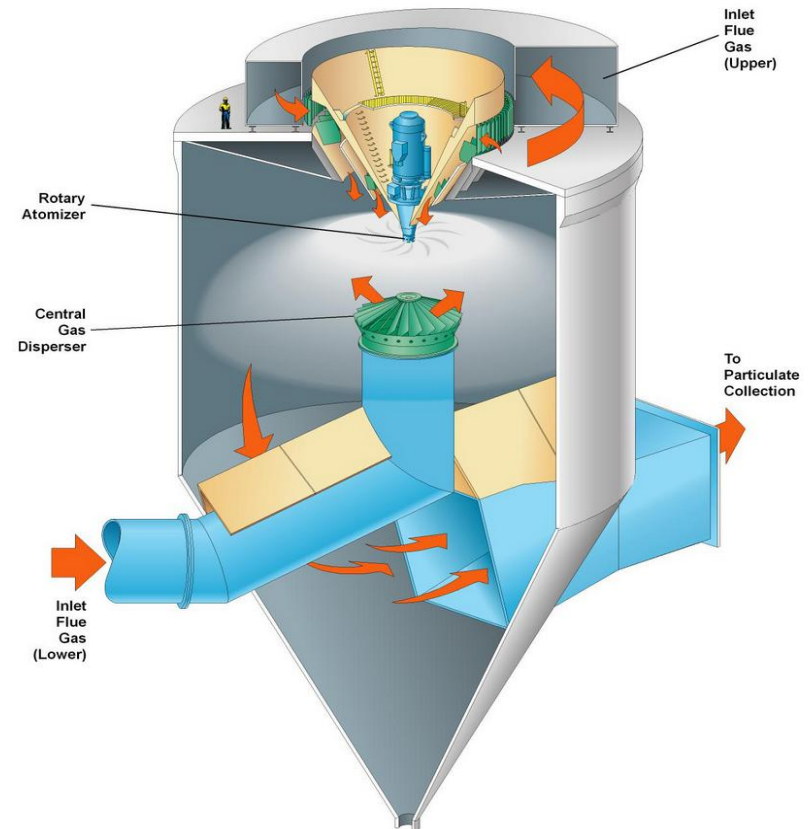
Q. Can SDA achieve high SO₂ removal efficiencies?

A. SO₂ removal efficiency in spray dryer absorbers is a function of stoichiometric ratio, gas temperature, and inlet SO₂ concentration. Typical removal efficiencies are in the range of 92-95%, but >98% is possible in some circumstances.

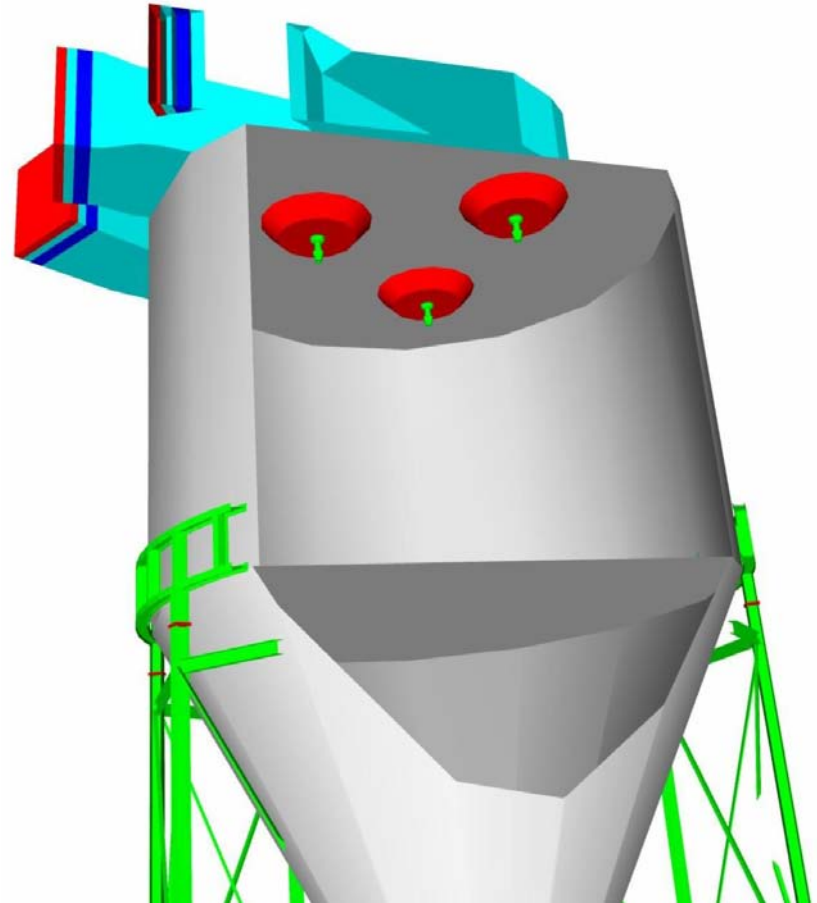


Single Rotary Atomizer SDA Design

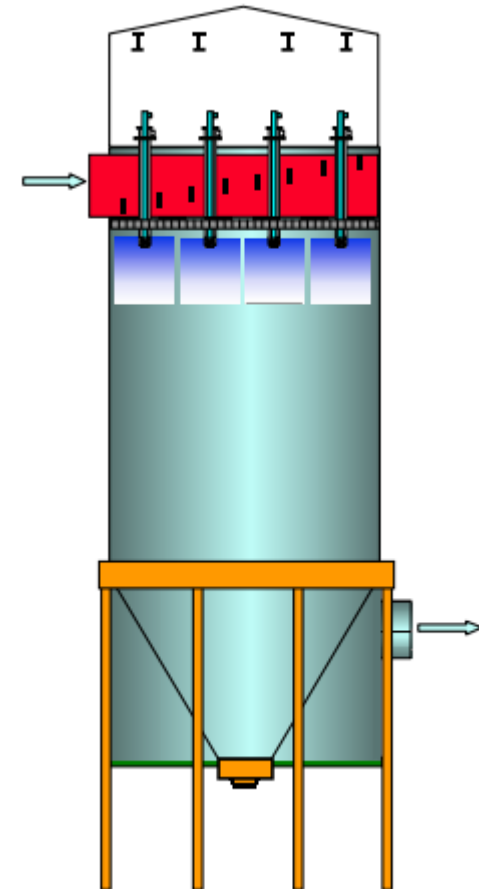
- Single large atomizer (up to 1000 hp)
- Large applications use 2 gas inlets to obtain required gas/liquid contact
 - Tangential spiral top inlet
 - Center inlet with disperser vanes



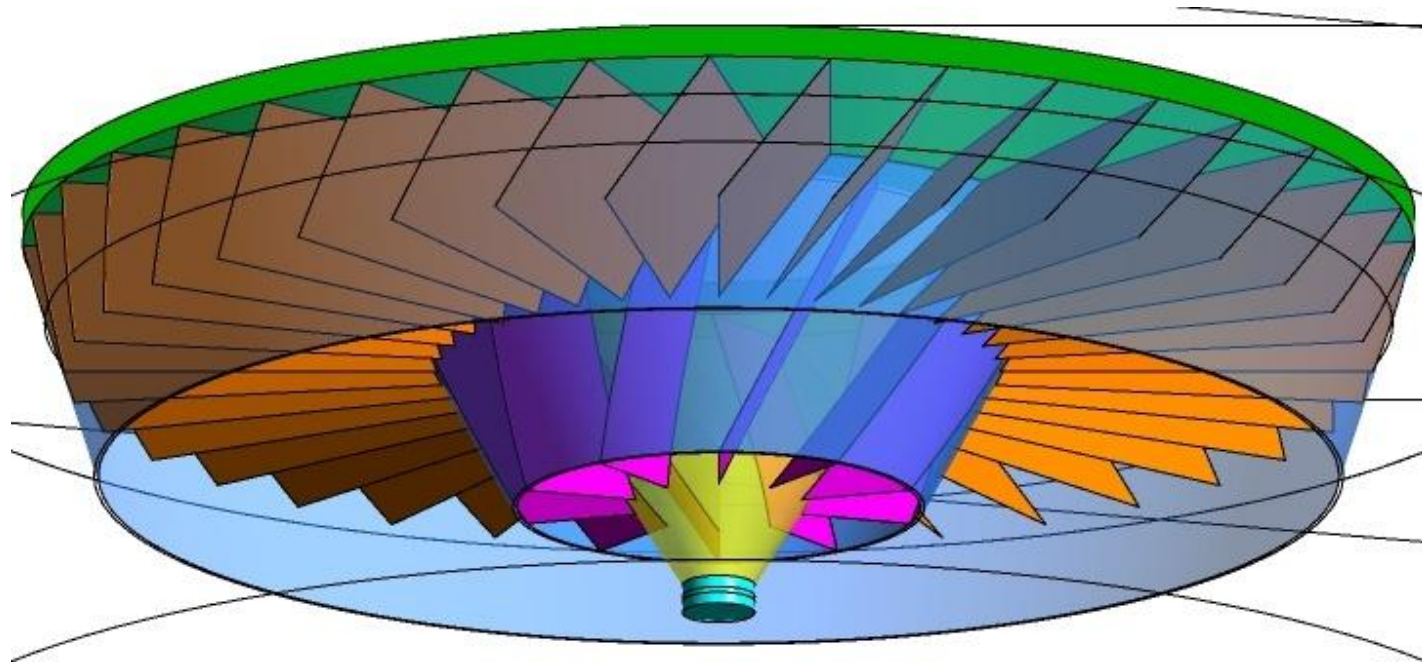
- Multiple atomizers (up to 400 hp)
- Each atomizer acts independently
- Typically designed to allow compliance at full-load with one atomizer out of service
- Top inlet with gas disperser to promote good gas/liquid contact
- No internals inside of Spray Dryer Absorber (SDA)



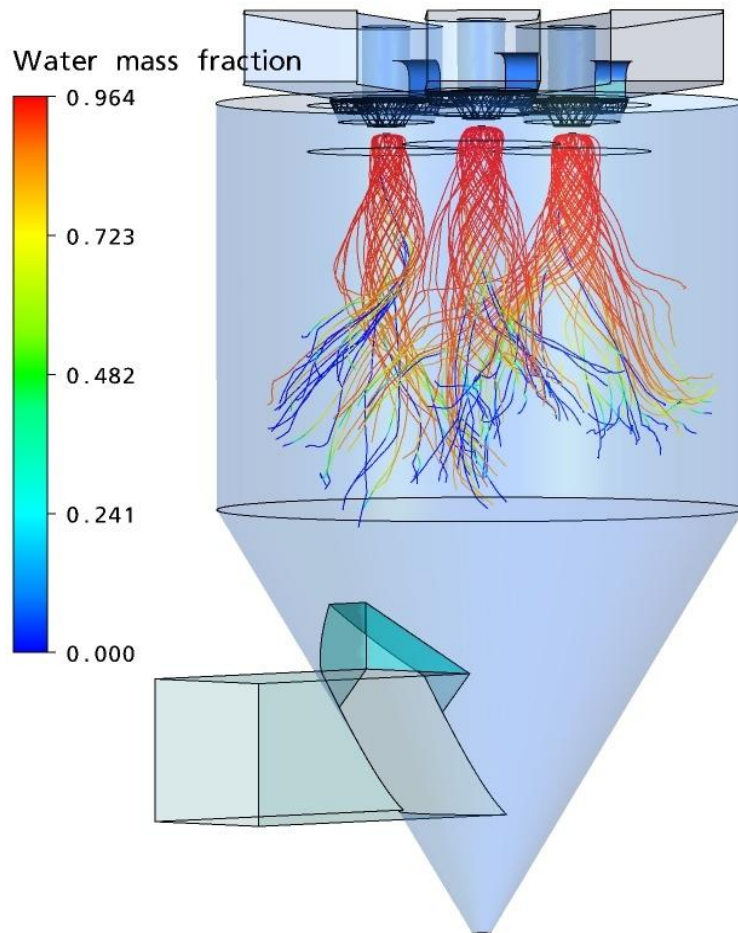
- Multiple dual-fluid nozzle assemblies
- Each atomizer acts independently
- Large number of nozzles minimizes impact of maintenance activities
- Side inlet with ladder vanes and egg crate to promote good gas/liquid contact
- No internals inside of Spray Dryer Absorber (SDA)



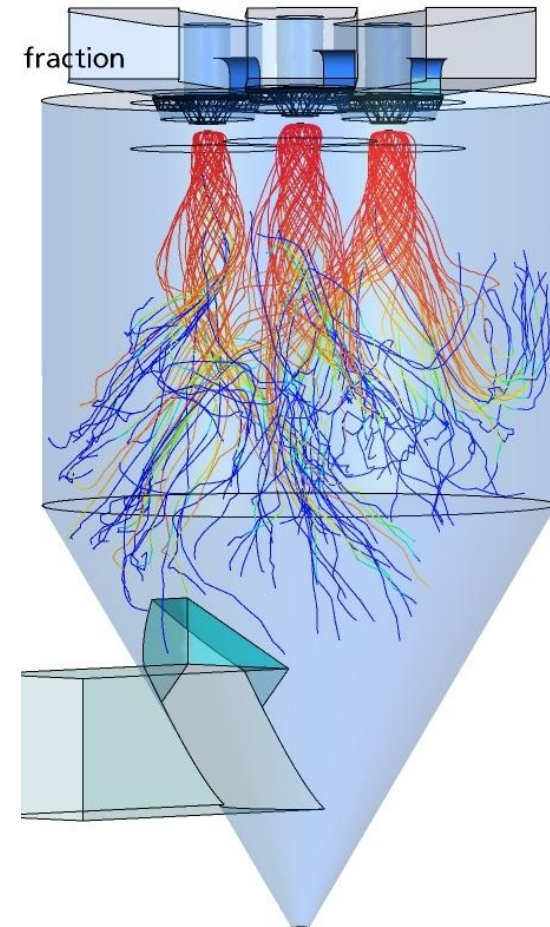
Rotary Atomizer Gas Disperser



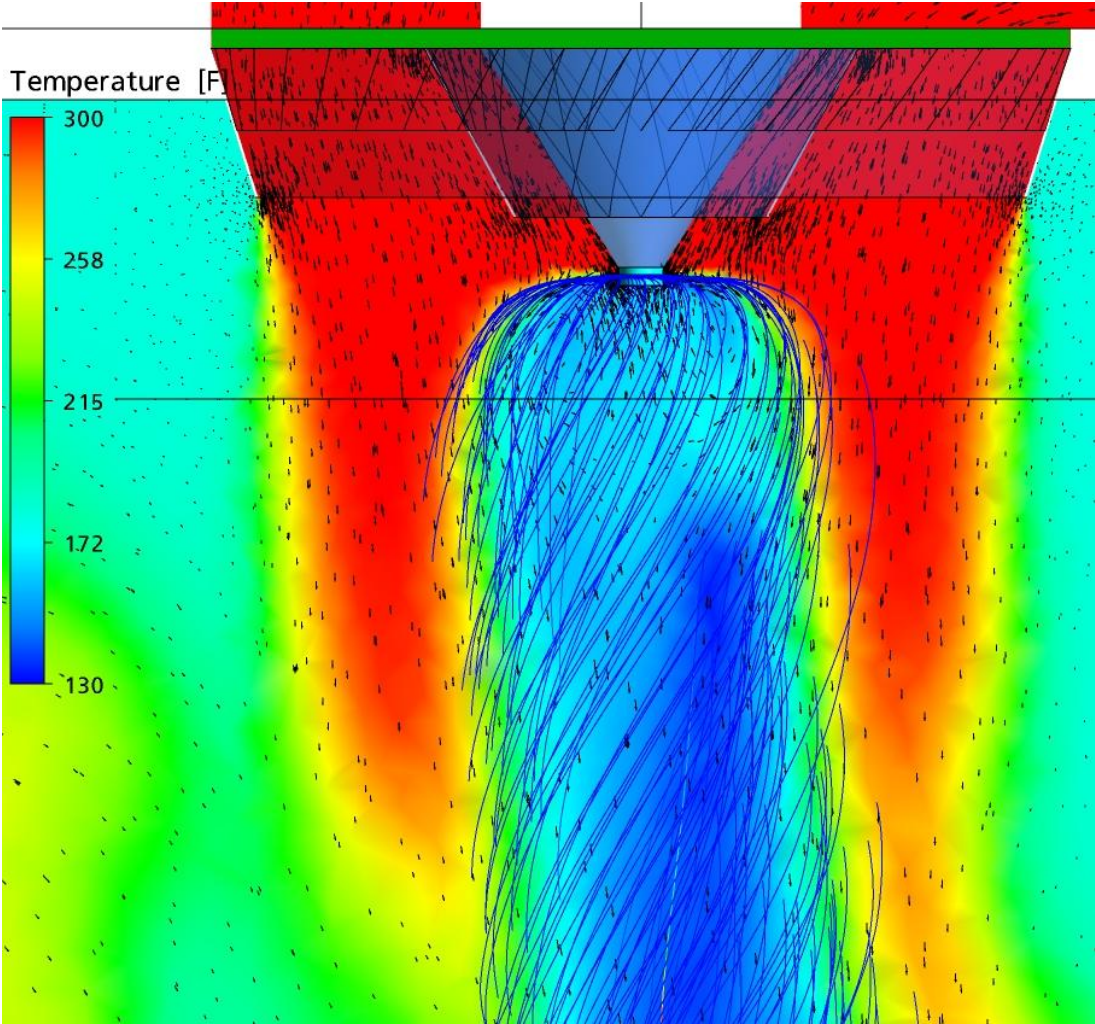
Rotary Atomizer CFD Model



Droplets, 1st second of travel

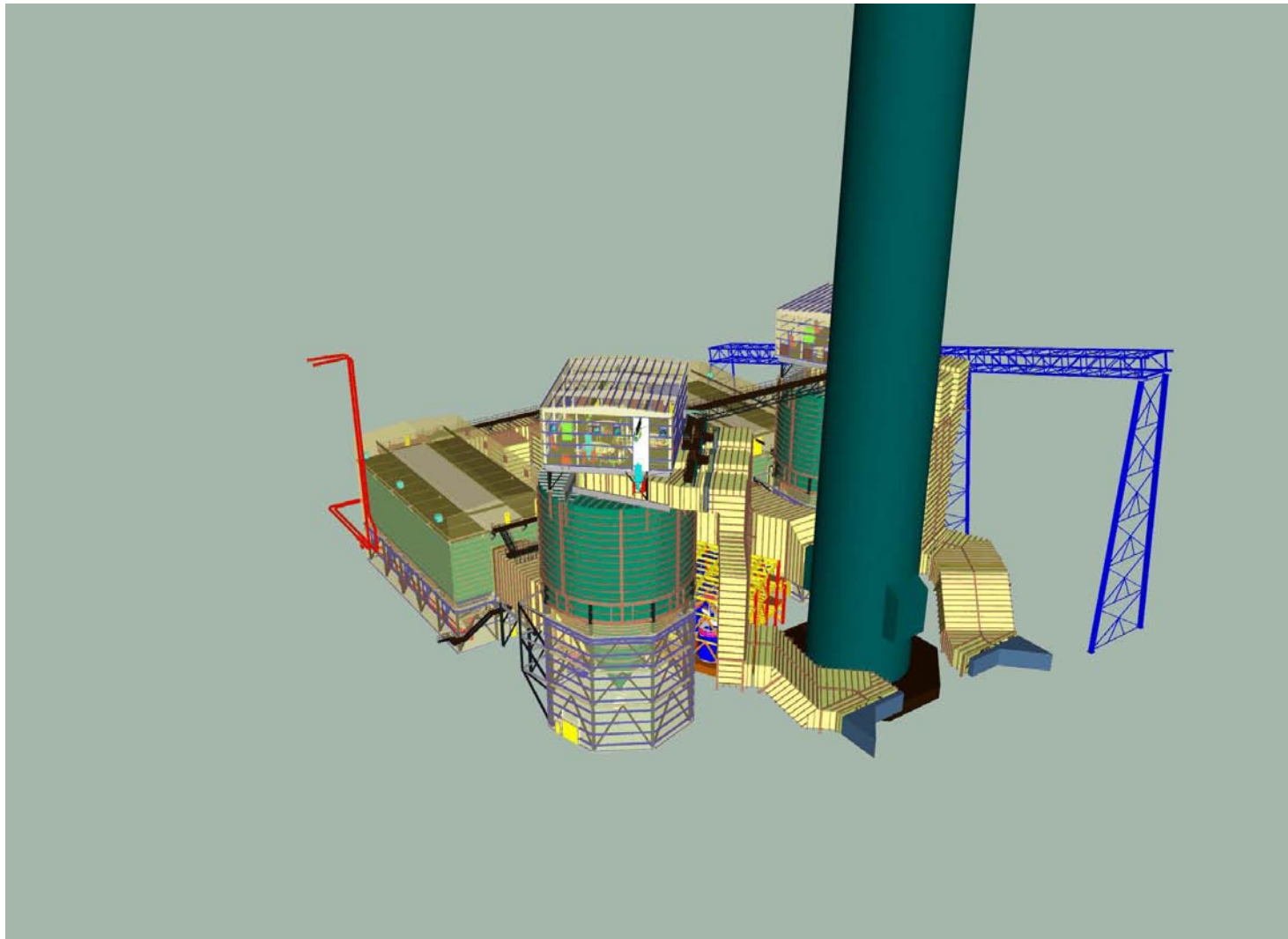


Droplets, 2nd second of travel

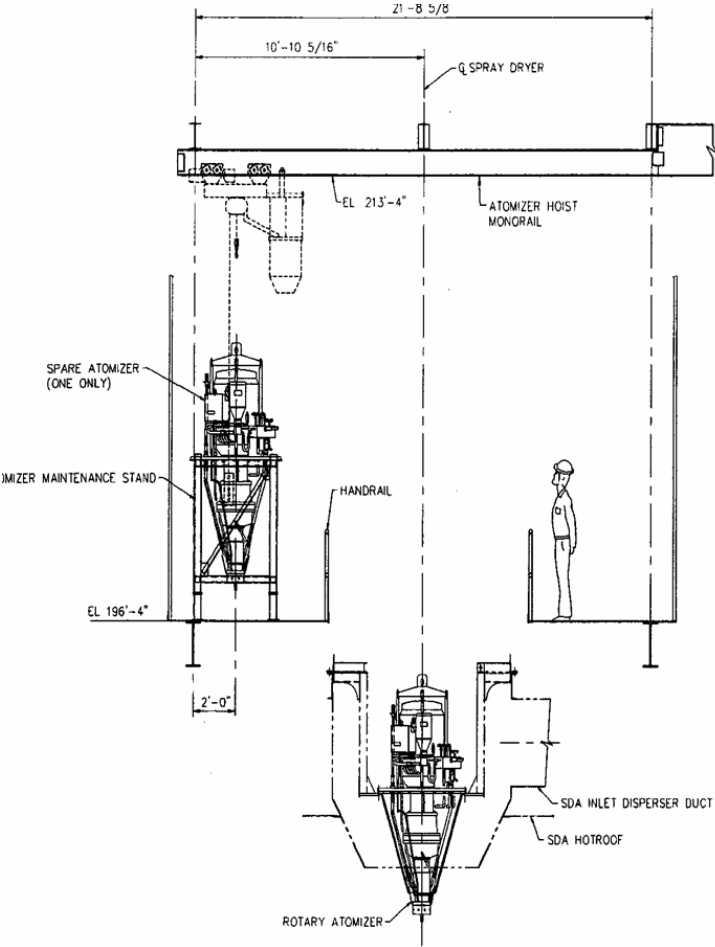


Zoom in on atomizer

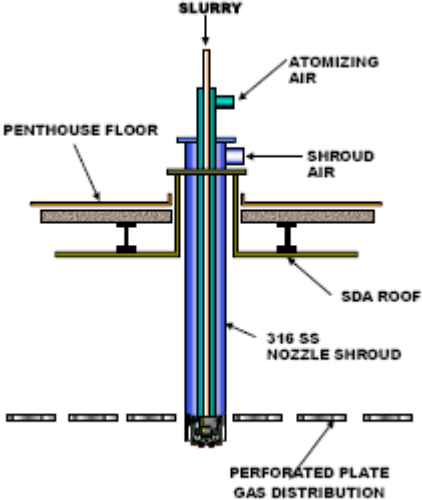




Rotary Atomizer Maintenance

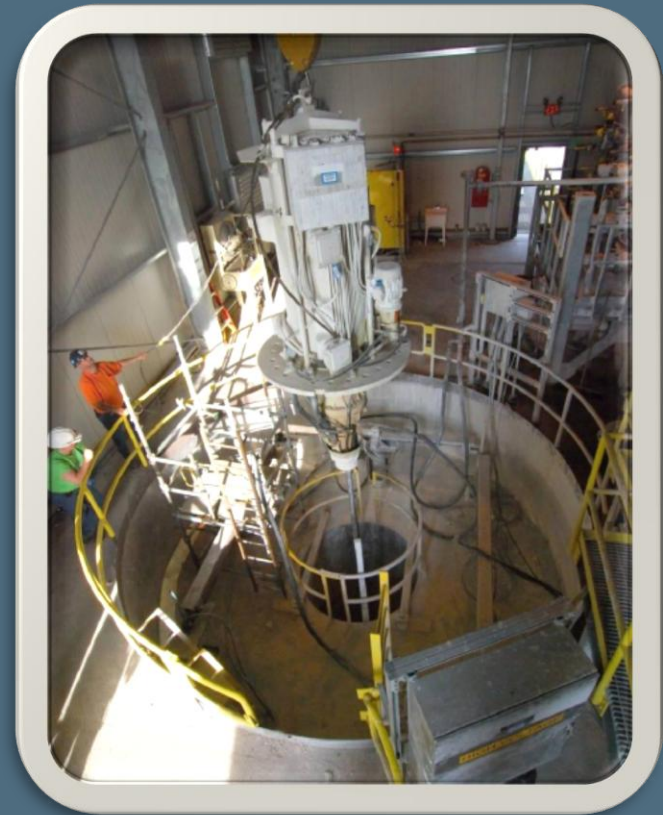


Dual-Fluid Nozzle Atomizer Maintenance



Q. How often do rotary atomizers have to be maintained?

A. Run time on atomizers varies widely depending on operating conditions such as water quality and ash quantity. Run times can range from 6-20 weeks.

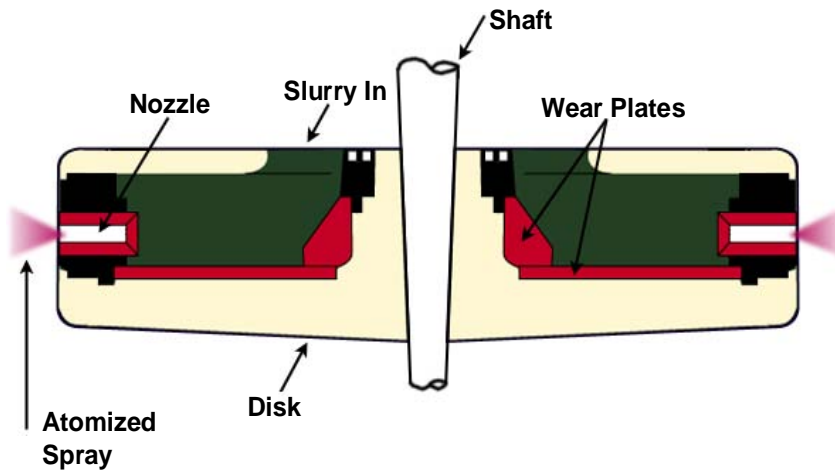


Q. How long does it take to change out a rotary atomizer?

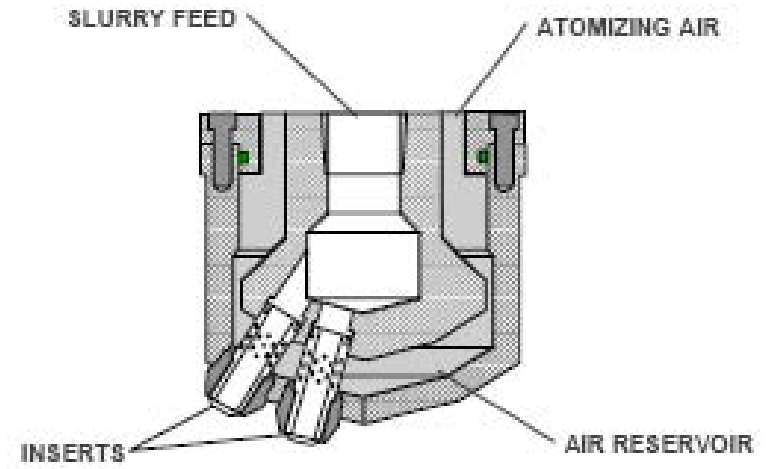
A. An experienced team of two individuals can accomplish the following activities in 30-60 minutes:

- Shut down operating atomizer
- Disconnect reagent, lube oil, and electrical leads
- Remove Atomizer A; transfer to stand
- Transfer Atomizer B to atomizer well
- Reconnect reagent, lube oil, and electrical leads
- Restart atomizer



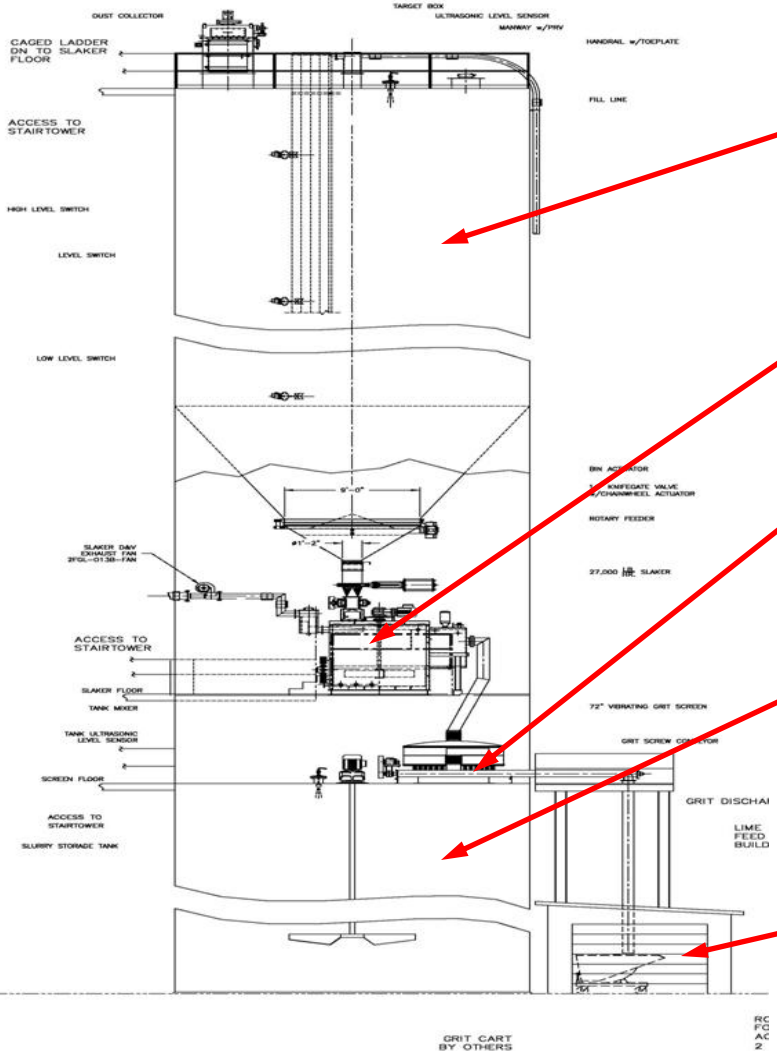


Rotary Atomizer Disc



Dual-Fluid Atomizer Head

Typical Lime Slaking System



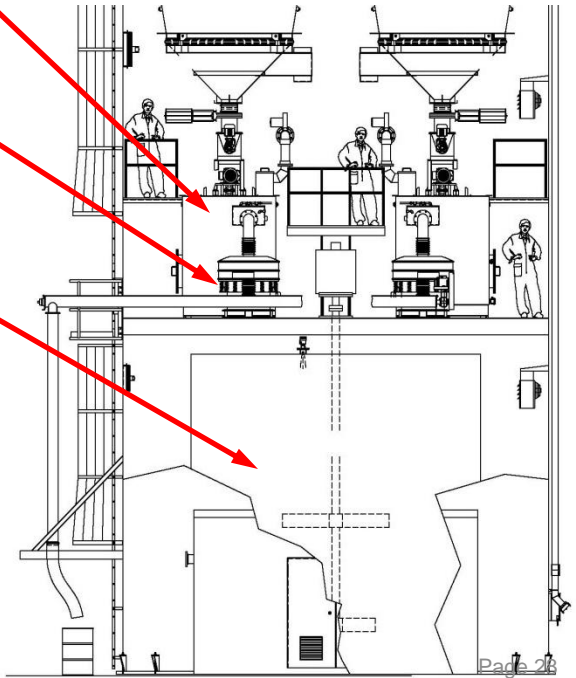
Lime Day Silo

Lime Slaker

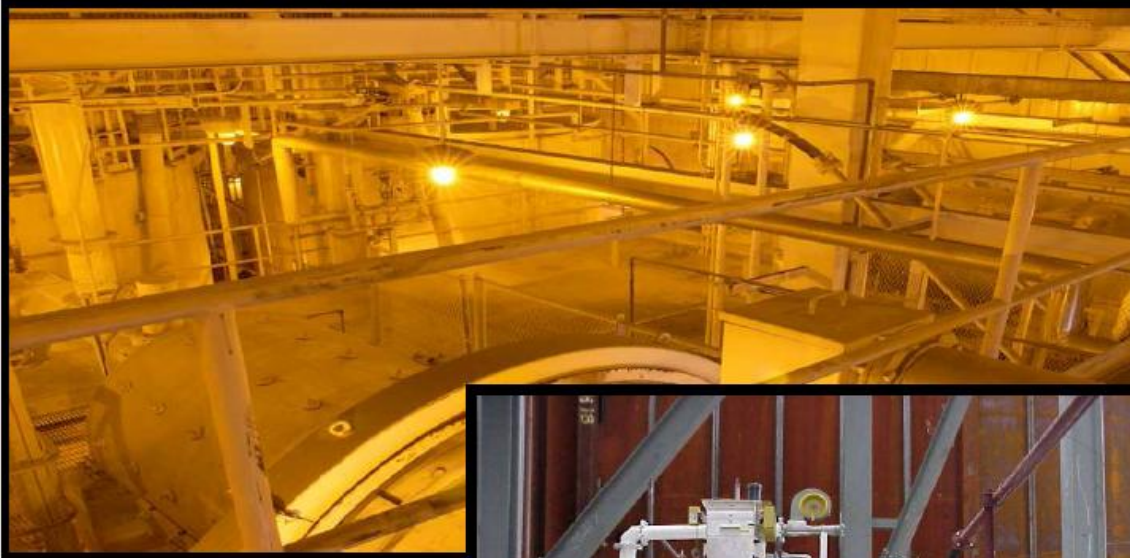
Grit Screen

Slurry Storage Tank

Lime Slurry Pump Bldg.



Horizontal Ball Mill

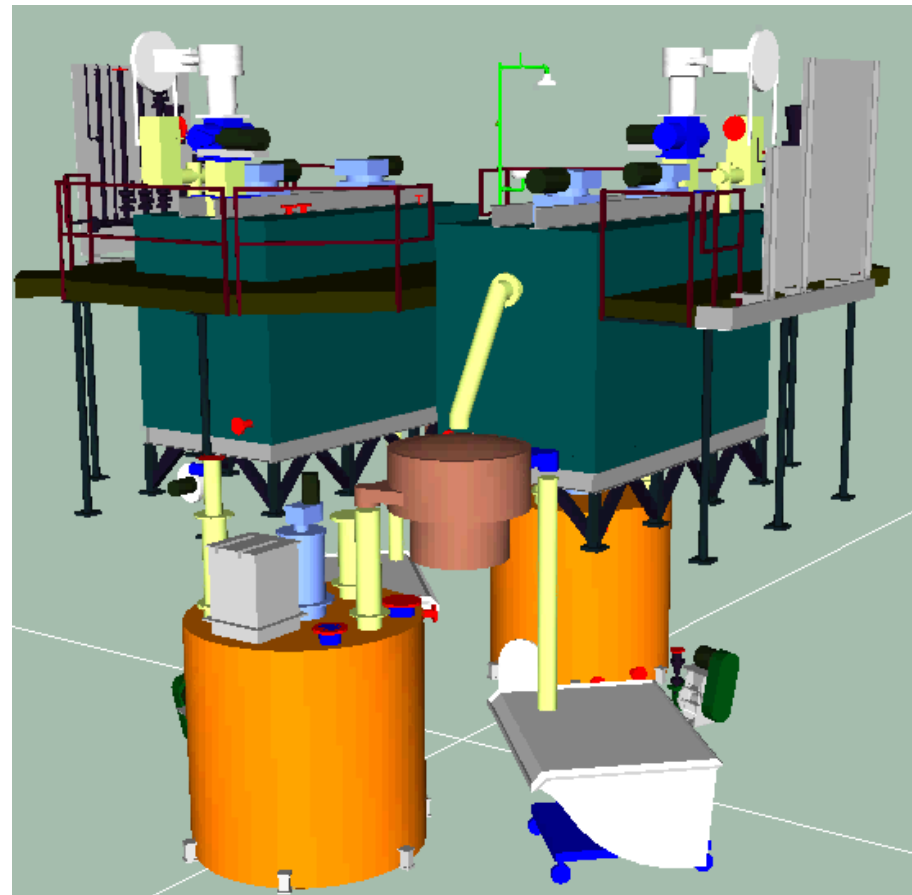


Detention Slaker



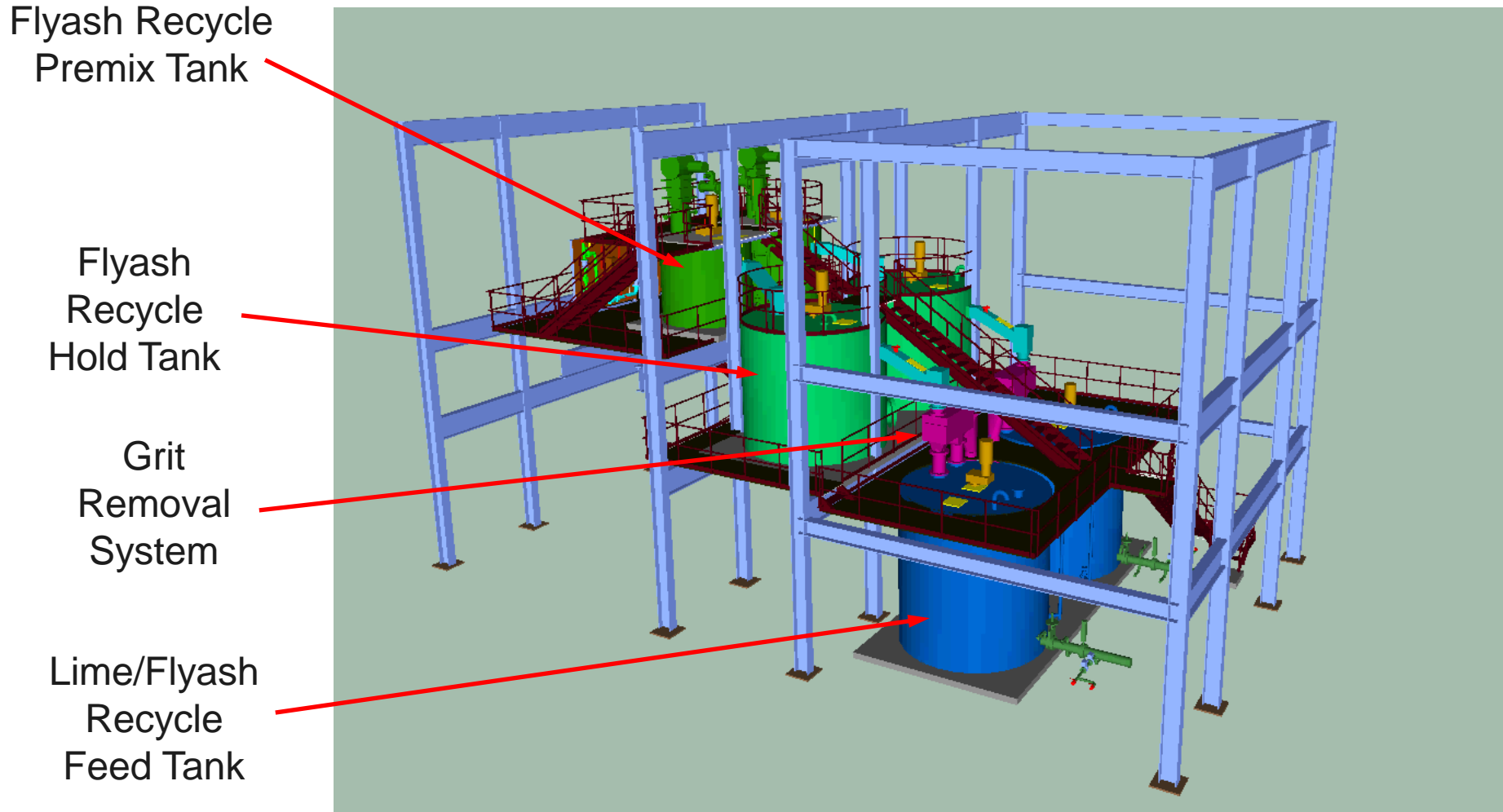
Vertical Ball Mill

Typical Lime Slaking System



- Temperature - 175 F +/- 5 F
- Diluted to 20% solids (Sp. Gr. 1.15 +/- 0.02)
- Settled Volume after 24 hrs >50 ml @ 10% solids
- Filtered to 20 mesh or less

Typical Recycle Preparation System



Introduction

DFGD Overview

SDA Technology

NID / CDS Technology

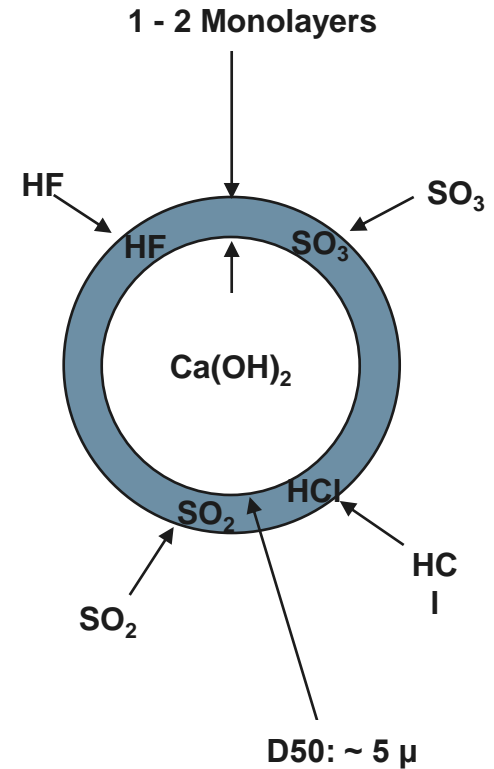
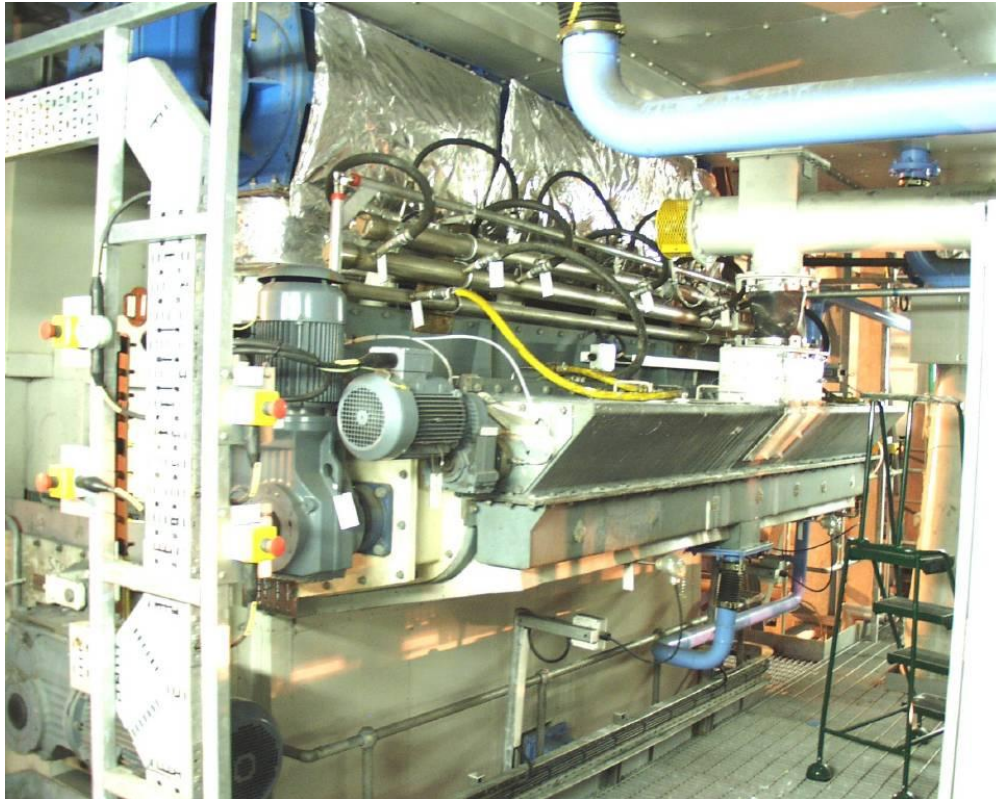
Fabric Filter Technology

Summary

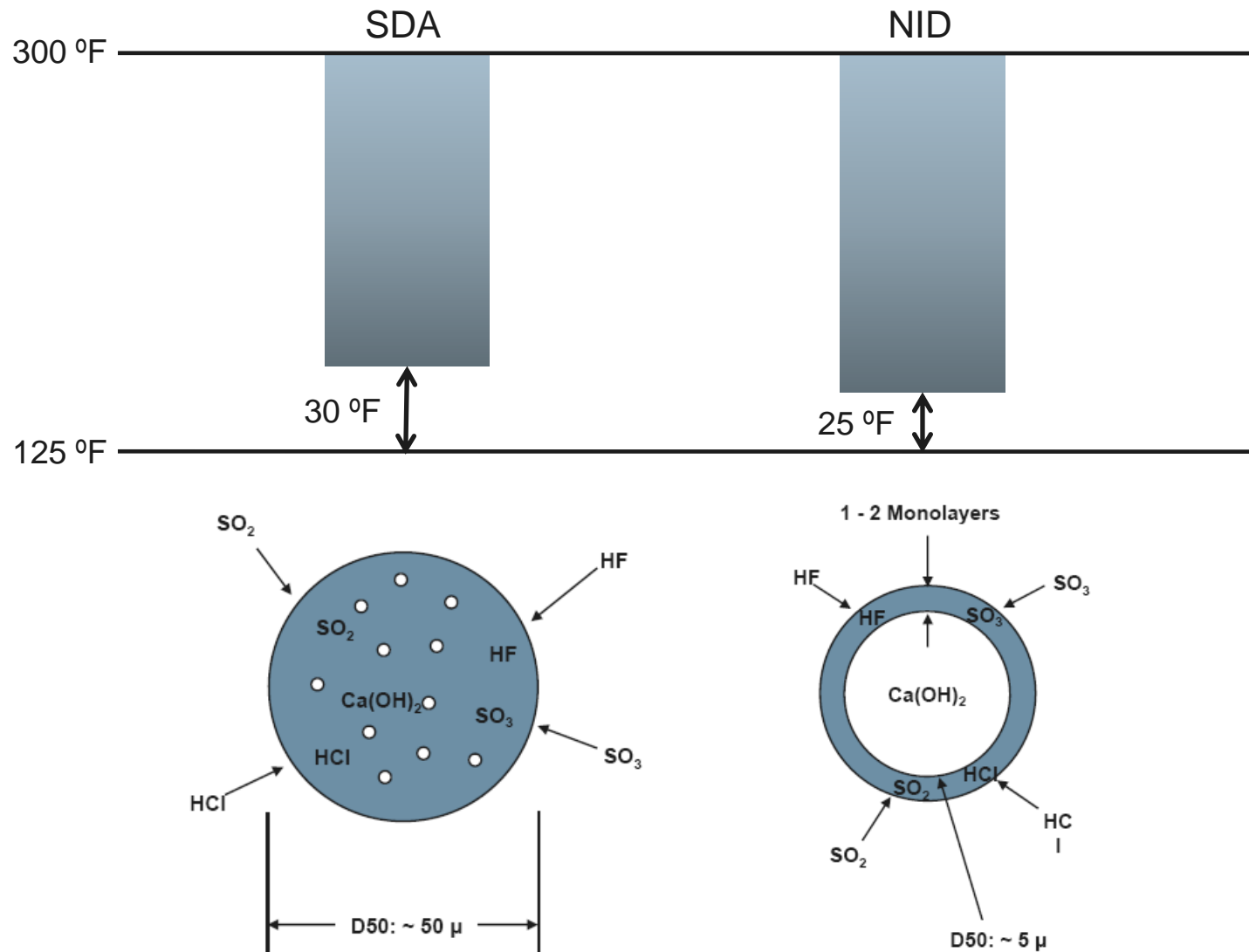
Key Benefits of NID / CDS

- Multi-pollutant control: High efficiency removal of SO₂, SO₃, PM, HCl, and HF
 - SO₂ removal: ≤ 98%
 - SO₃ emissions: < 1 ppm
 - PM (filterable): < 0.012 lb/MBtu
- Lime-based semi-dry FGD technology
 - Patented, integrated hydrator/mixer – no slurry handling (NID only)
 - Zero liquid discharge
 - Low water consumption; ability to use low quality water: CTB, WFGD purge
- Simple, compact design
 - Small footprint offers retrofit advantage
 - Low capital cost
 - Low BOP/construction cost
 - Low O&M cost
- Modular design (NID only)
 - High reliability
 - Excellent turndown
 - No scale up issues
- Fuel flexibility of up to 2.5% sulphur coal or higher

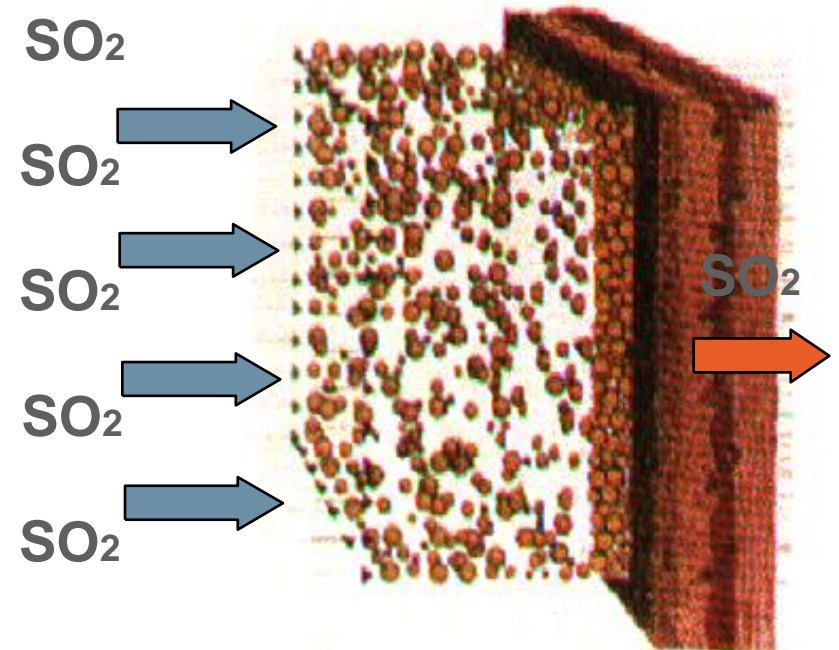




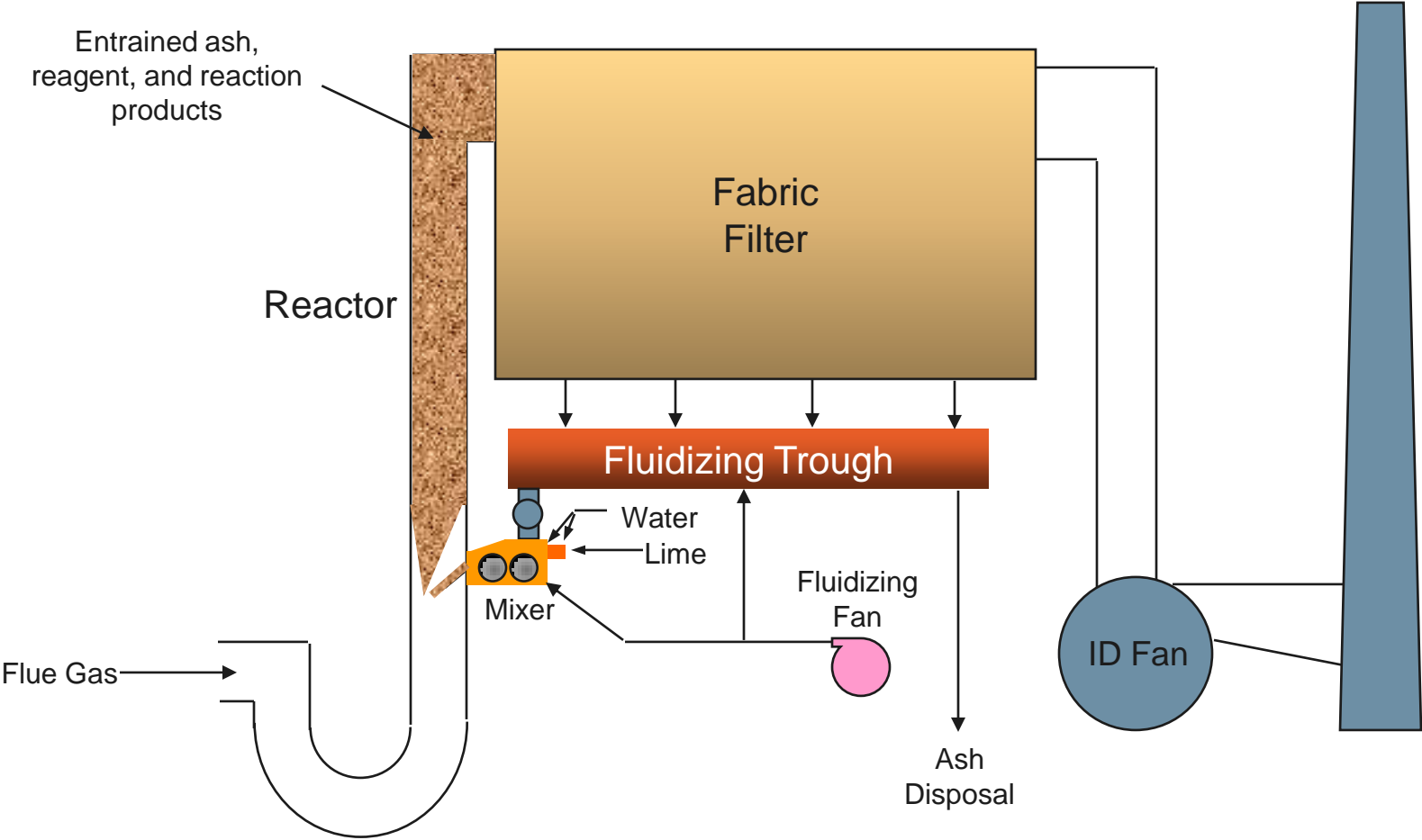
DFGD Technology Comparison

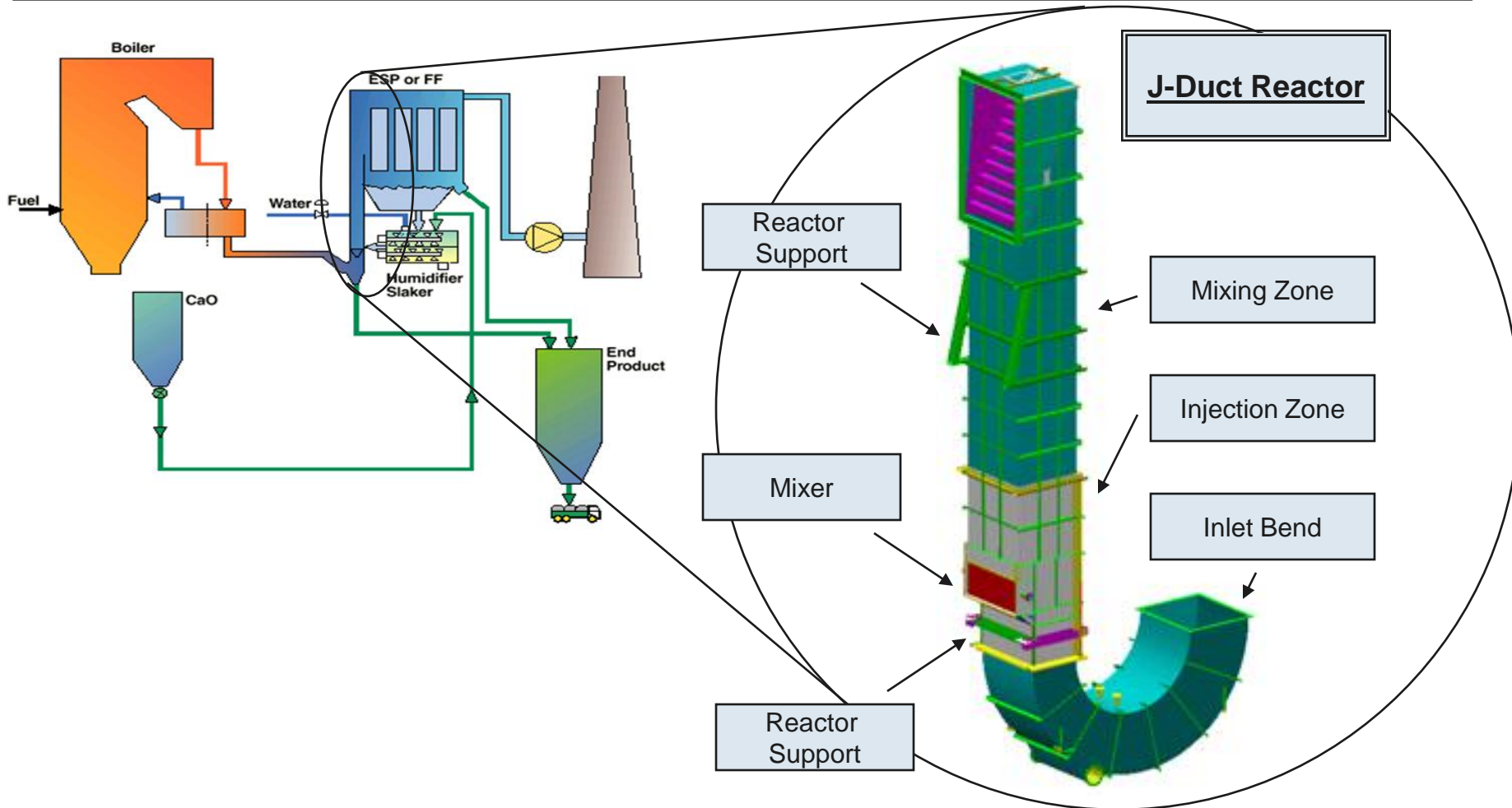


- Second Stage Reaction
 - SO_2
 - SO_3
 - HCl / HF
 - Hg
 - Other trace elements
- Collection
 - Fly ash
 - Carbon



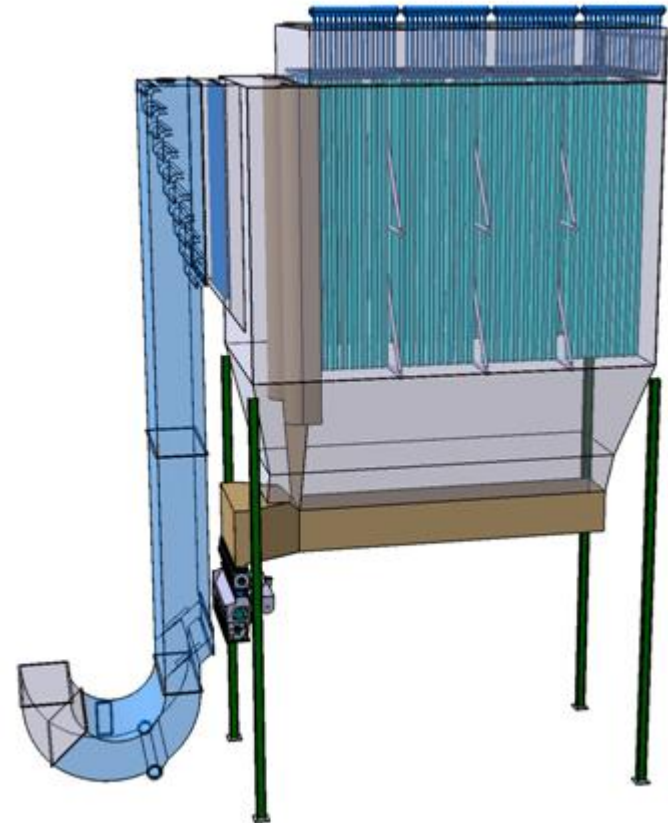
NID Flow Diagram





Continuous Recirculation – No Slurry Handling – Dry Stack

- Multiple, independently isolatable modules
- Dampers
 - Upstream of reactor
 - Downstream of FF compartment
- Nominal gas flows corresponding to 15 - 90 MW per module
- Can be designed to achieve emissions guarantees at full load with one module out of service



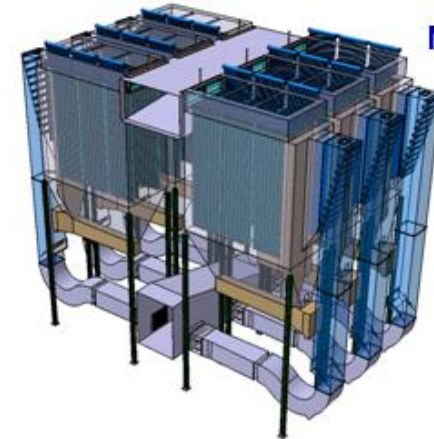
Allows for Turn-Down up to 50% without Recirculation

Walk-in plenum



NID 4+4

Top Doors

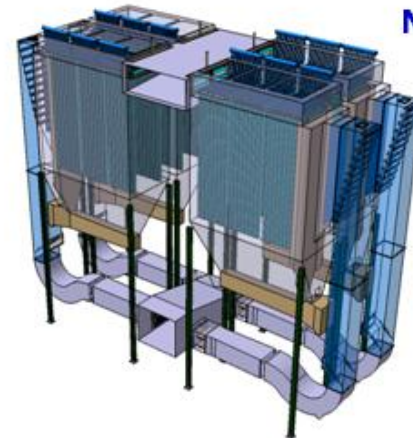


NID 3+3

Gas outlet with Poppet Dampers



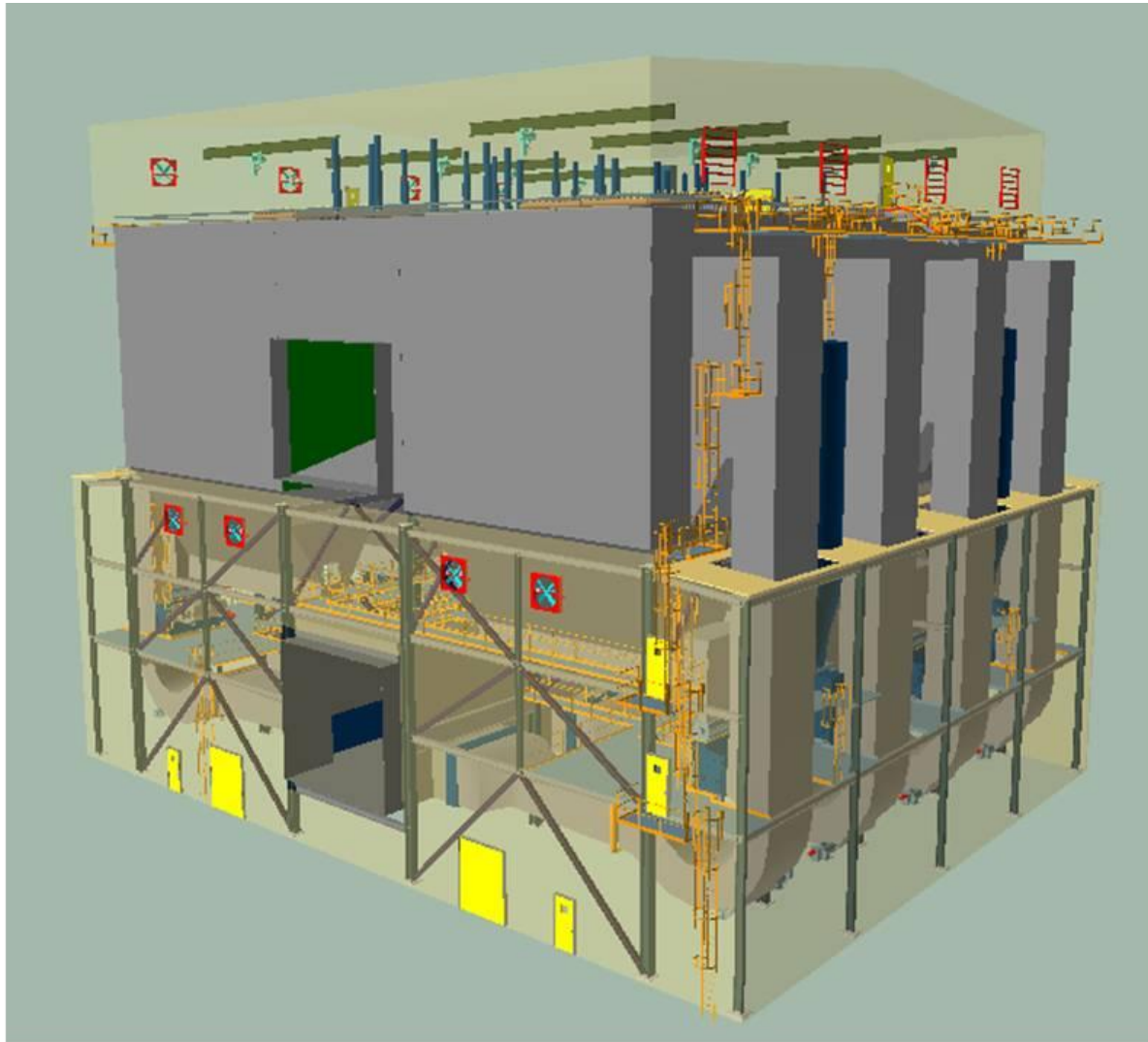
Gas outlet with Louver Dampers



NID 2+2

Modularization Offers Design Flexibility

NID Arrangement



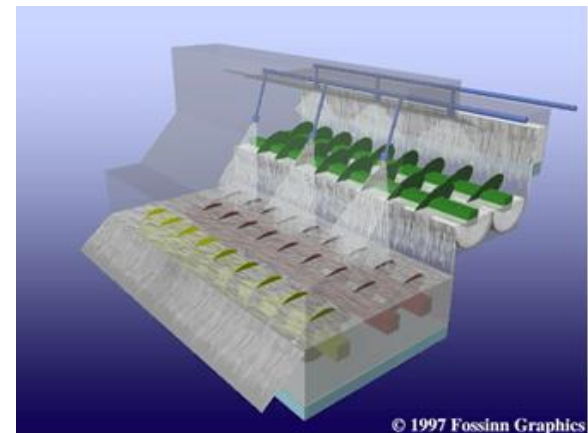
- Concept

- Mixing humidified recirculation end product and hydrated lime
- Hydration in separate compartment integrated with the NID Mixer
- CaO feed controlled directly, based on SO₂ emission
- Hydrated lime added to mixer by displacement of CaO addition; overflow directly into mixer section

- Advantages

- No intermediate silo
- No separate filter - venting through NID FF
- No transport of hydrated lime - direct overflow into the NID Mixer

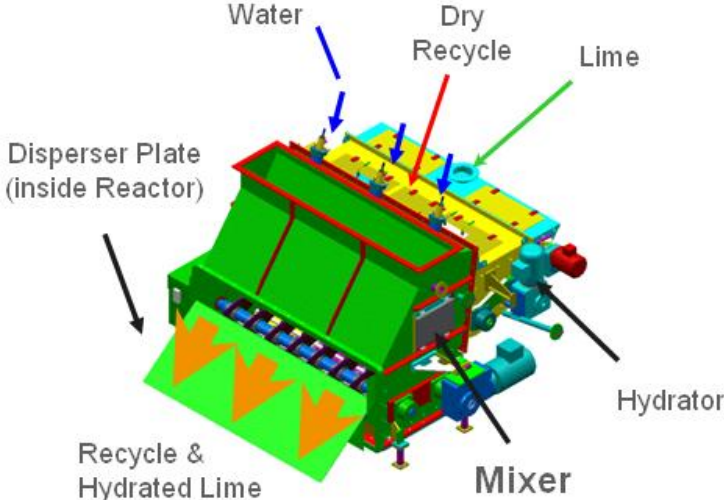
Mixer / Hydrator



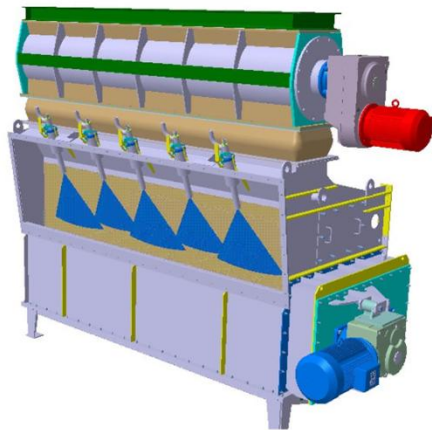
© 1997 Fossinn Graphics

Mixer / Hydrator

Key Components

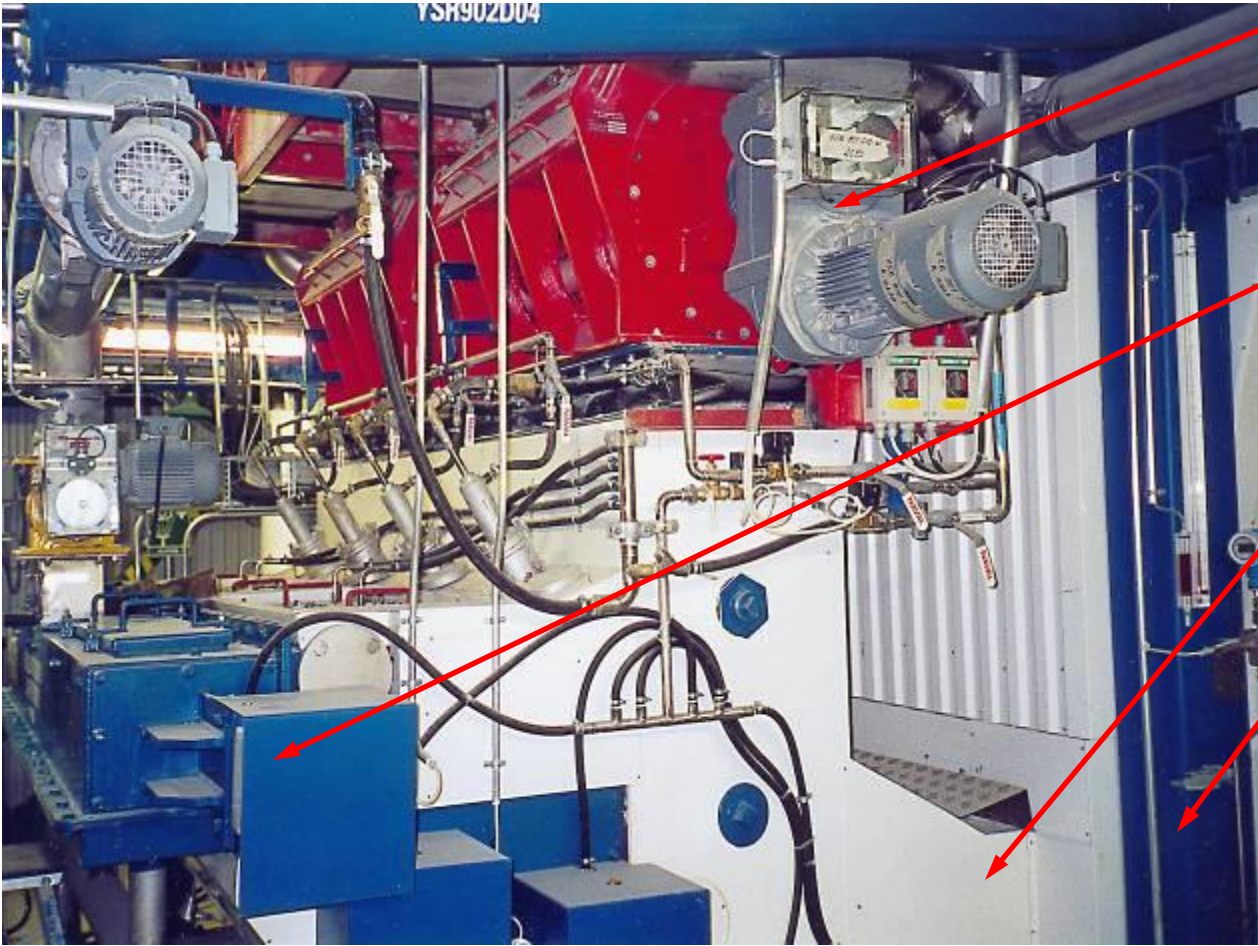


Water Spray System



Mixer / Hydrator

Rotary Air Lock and Mixer/Hydrator



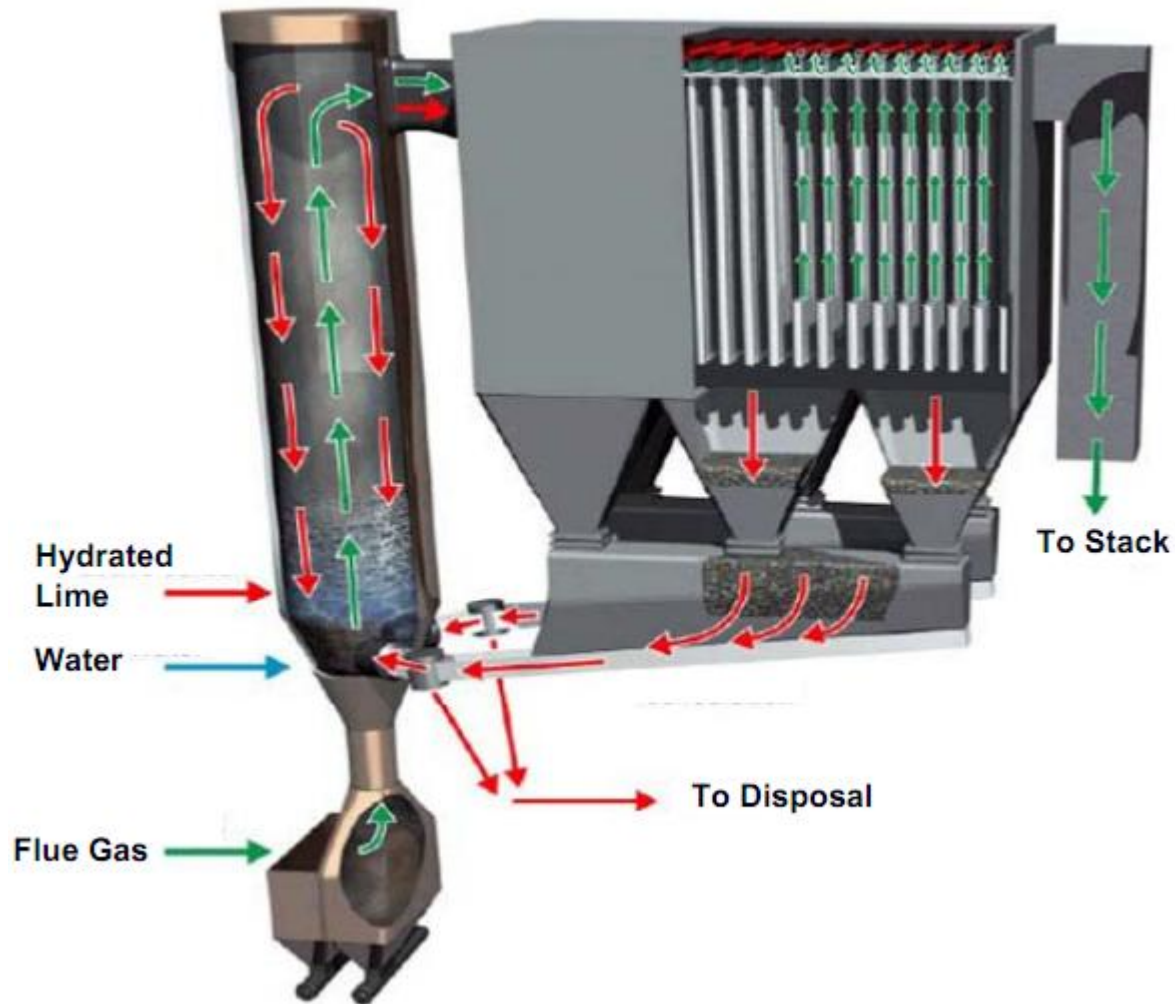
Recirculation rotary valve

Lime Hydrator

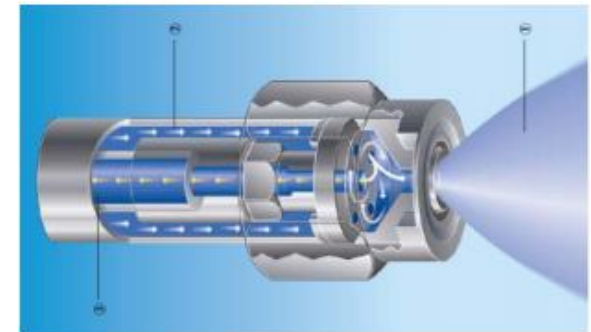
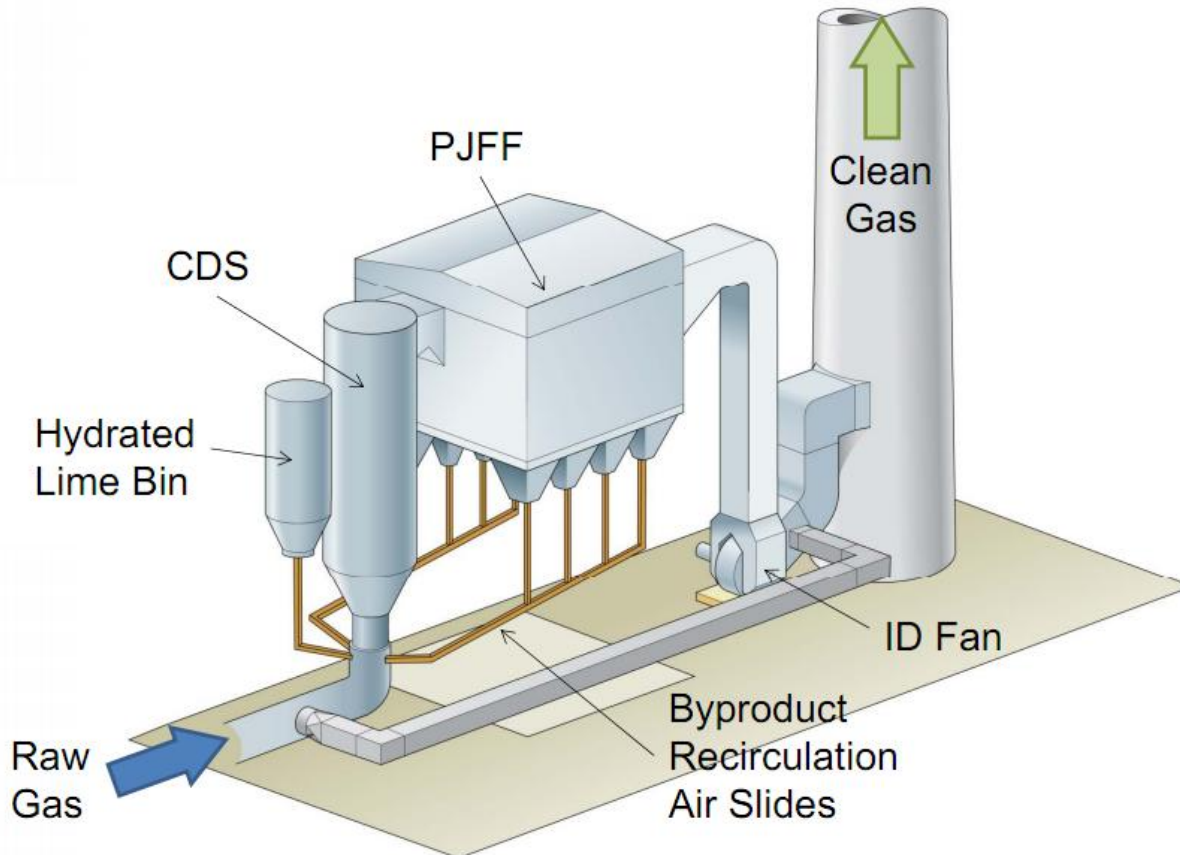
Mixer

Reactor

CDS Flow Diagram



CDS Arrangement

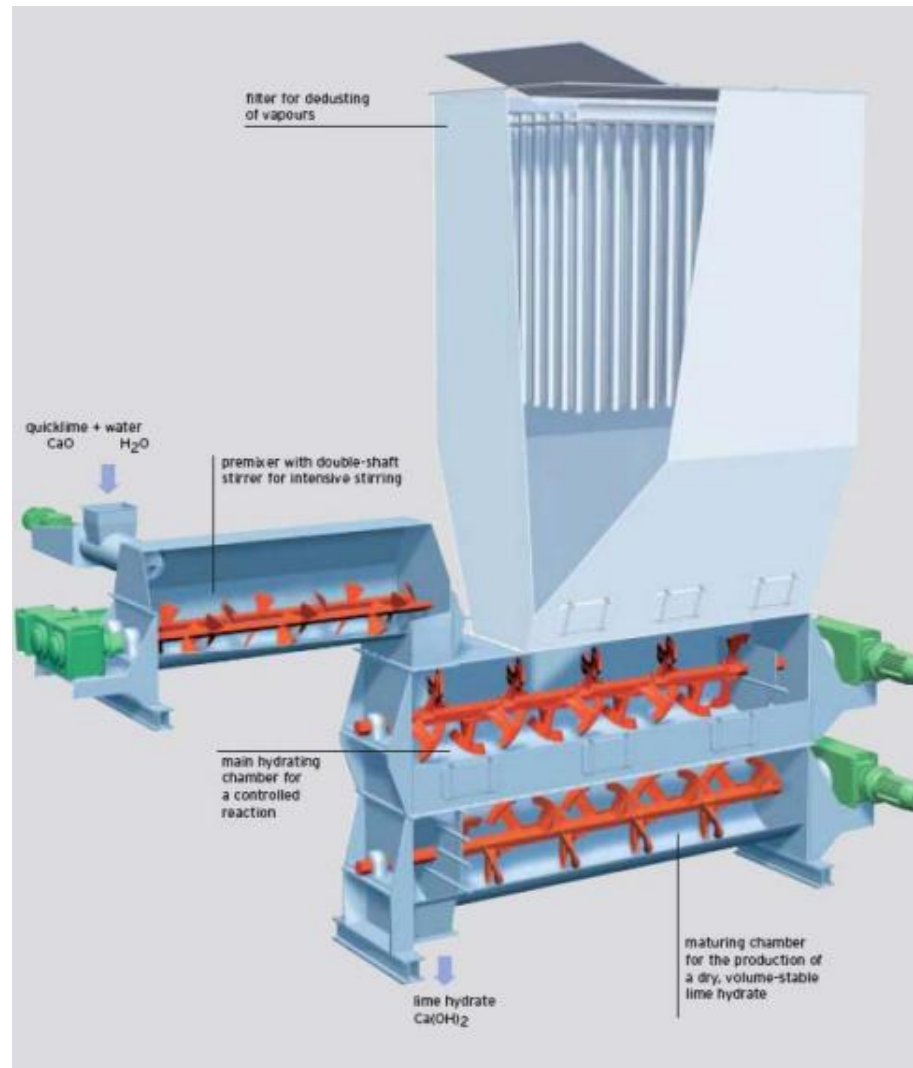


Water Injection Nozzle

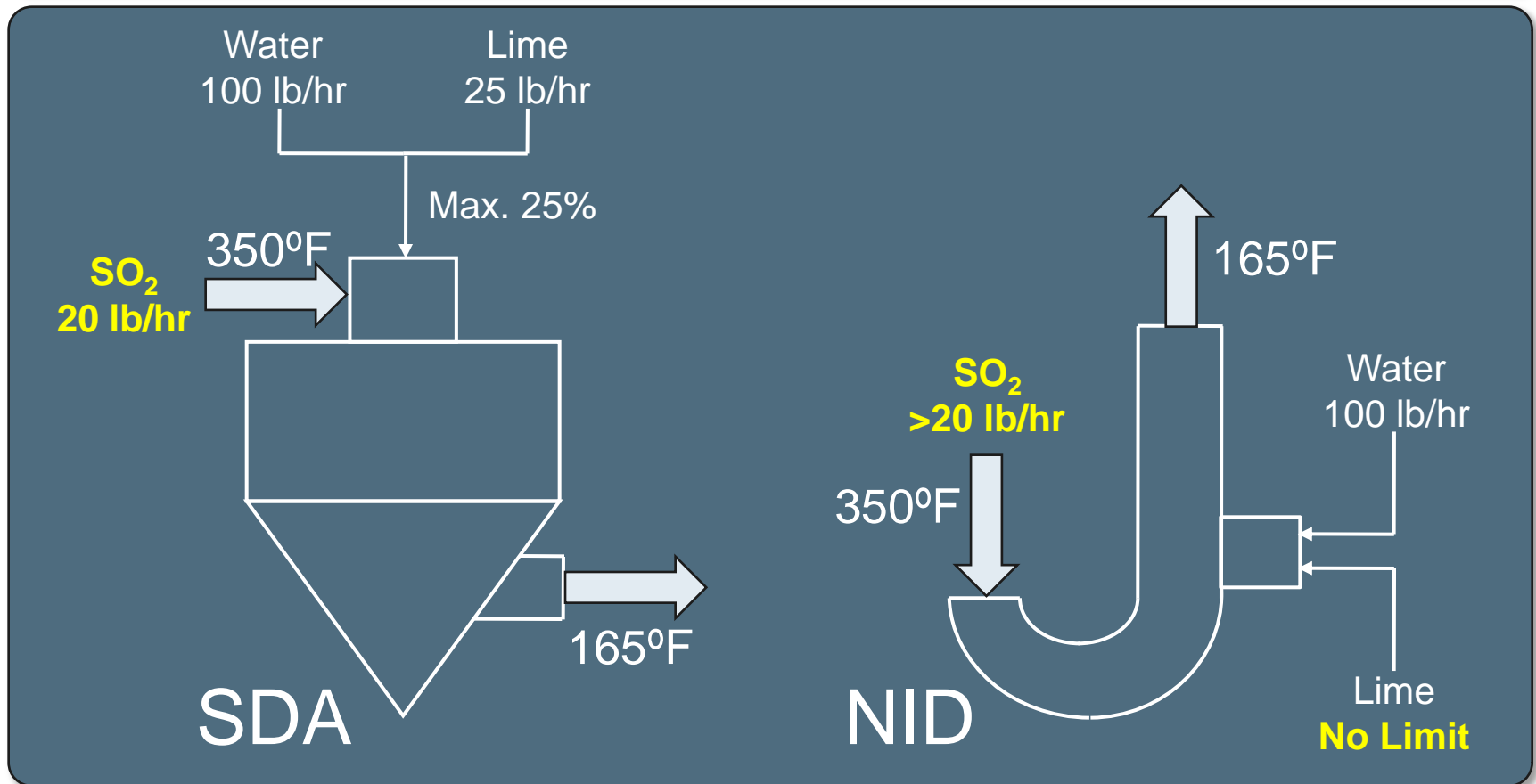


High Pressure Pumps

Lime Hydrator



Q. Why can NID achieve higher removal than SDA?



Q. What's the difference between NID and SDA systems?

SDA

20-40% solids

12 sec. residence time

Lime/water flows linked

2-4:1 recycle rate

NID

4-5% moisture

1-2 sec. residence time

Lime/water flows independent

50-100:1 recycle rate

Introduction

DFGD Overview

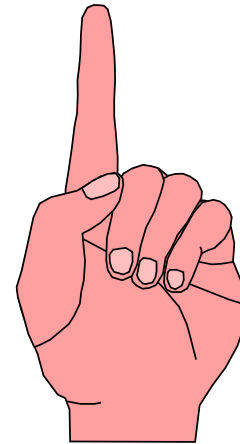
SDA Technology

NID / CDS Technology

Fabric Filter Technology

Summary

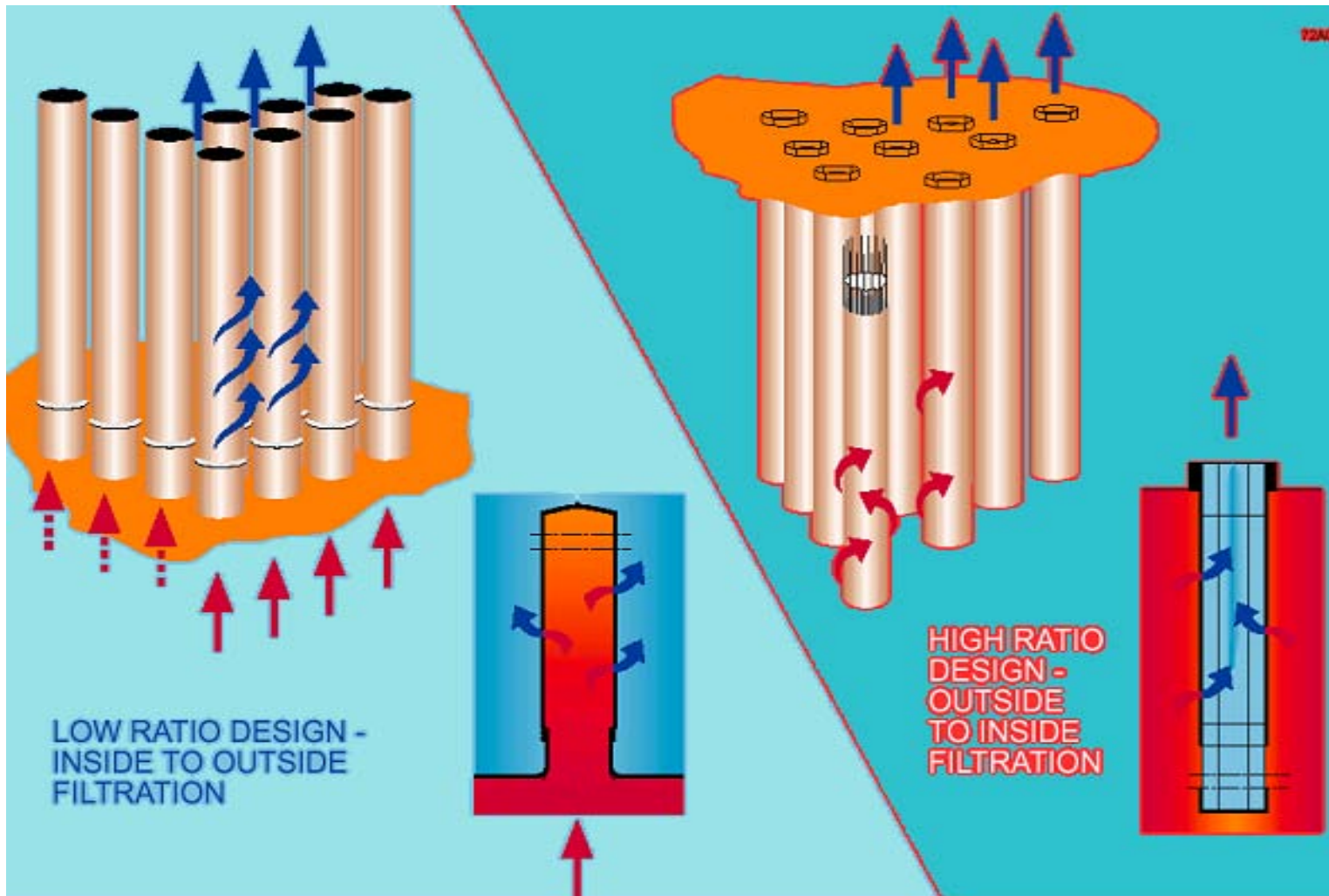
- Filter Type
- Size (A/C Ratio)
- Filter Bag Material
- Bag Geometry
- On-Line Maintenance (NET, NET1, NET2)
- Structural/Modular Fabric Filter
- Inlet/Outlet Plenum Arrangement
- Inlet/Outlet Dampers
- Hoppers (Pyramidal/Trough)
- Maintenance Access
- By-Pass Dampers
- Thermal Expansion
- Controls and Monitoring



Fabric filters can be classified according to many different criteria, configuration, cleaning method, shape of fabric etc. Below summarizes the most common criteria:

- Cleaning method : Pulse jet, Reverse gas
- Cleaning condition : On-line, Off-line
- Direction of gas flow : Outside to inside, Inside to outside
- Shape of filter fabric : Bag, Envelope/Cartridge
- Filtration velocity : High Ratio (4:1), Low Ratio (2:1)

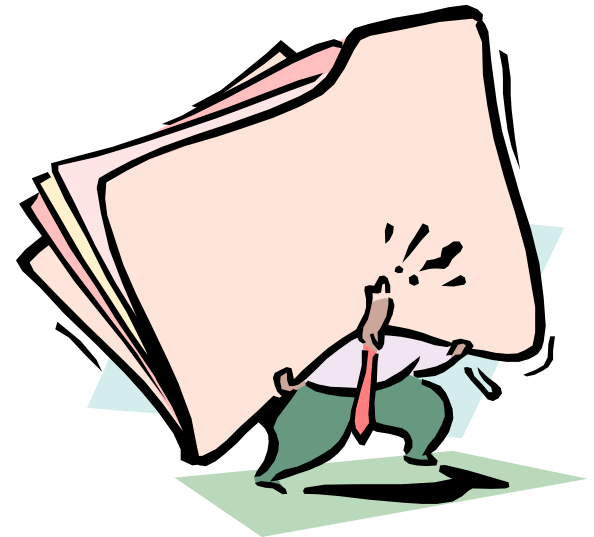
Fabric Filter Designs



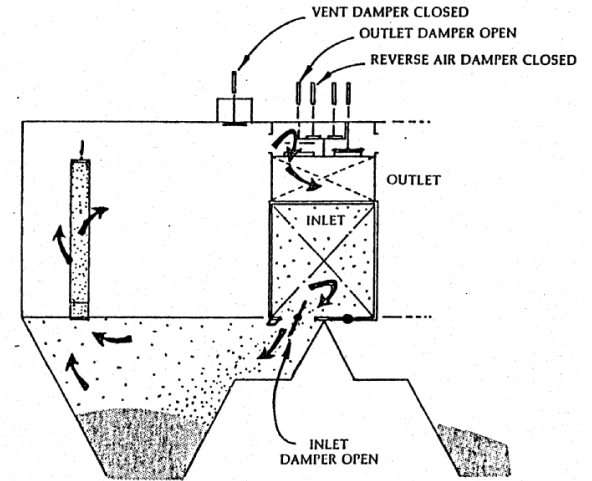
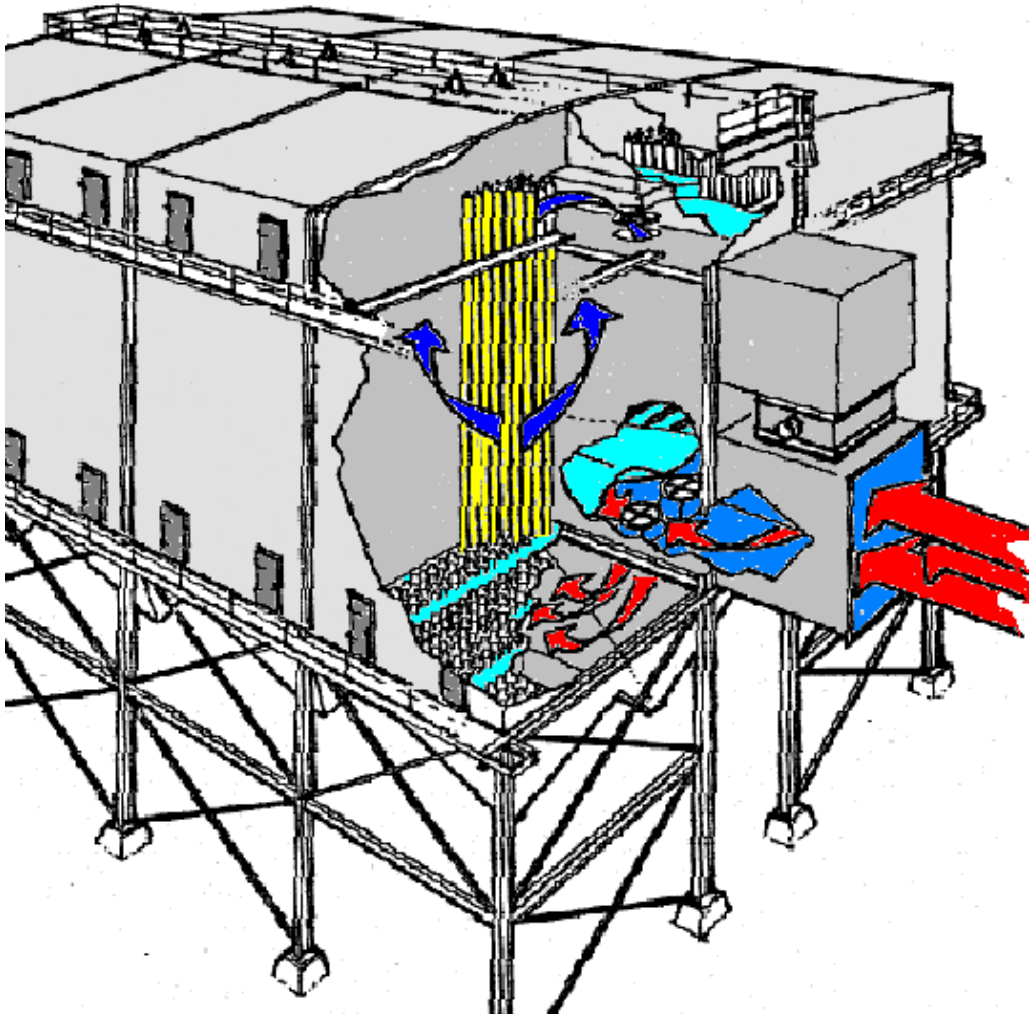
BAG DIA - 130 MM
(5 1/8 in.)
BAG LENGTH - 10
M (~33 ft)
TYPICALLY ON
LINE CLEANING

BAG DIA - 300 MM (~12 in.); BAG LENGTH - 11 M (~36 ft)
OFF LINE CLEANING

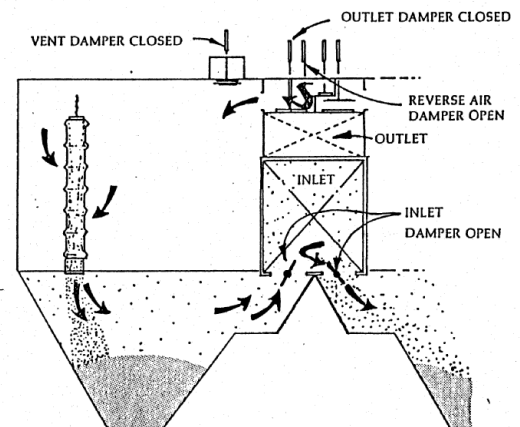
- Reverse Gas (Air to Cloth 2.0 to 1 Net 2)
 - Higher First Cost
 - Large Foot Print
 - Longer Bag Life (13 years with PRB coal ash)
- Pulse Jet (Air to Cloth 4.0 to 1 Net 1)
 - Lower First Cost
 - Smaller Foot Print
 - Shorter Bag Life (3-5 years)



LRFF Design

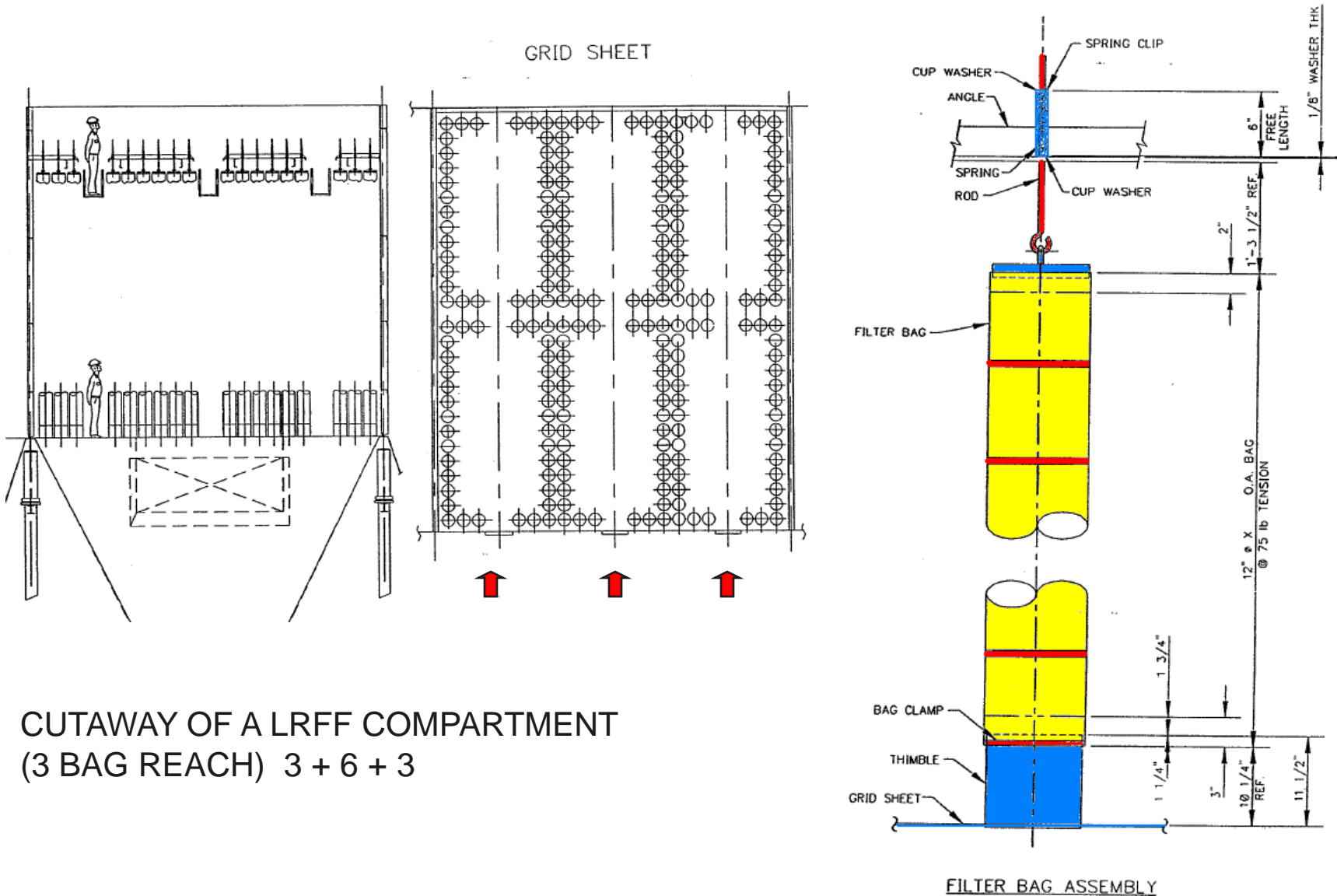


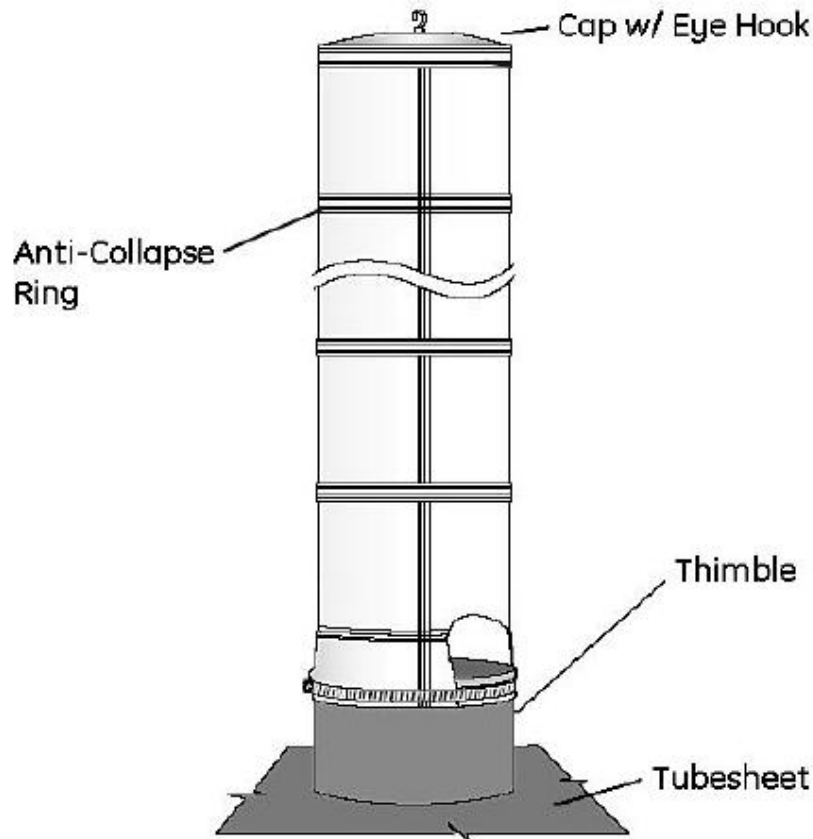
NORMAL FILTERING



AUTOMATIC FABRIC CLEANING

LRFF Design





Typical. LRFF Bag
(snap band bottom connection available)



Tensioning Assemblies



LRFF Design with Sonic Assist Cleaning

Typical LRFF Bag Construction

- > Woven Fiberglass
- > ePTFE Membrane on Fiberglass

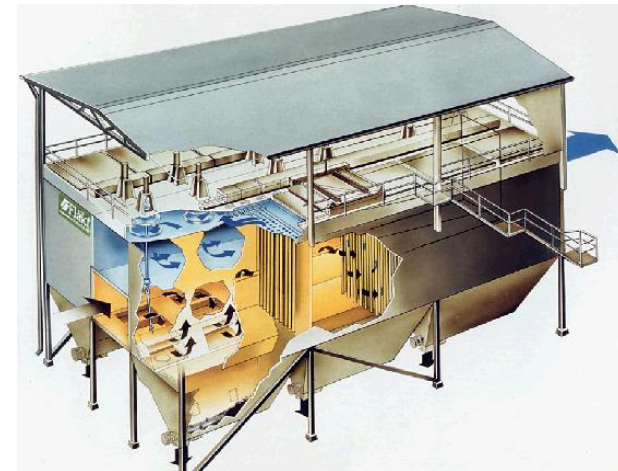


Reverse-Air
Bag Manufacturing

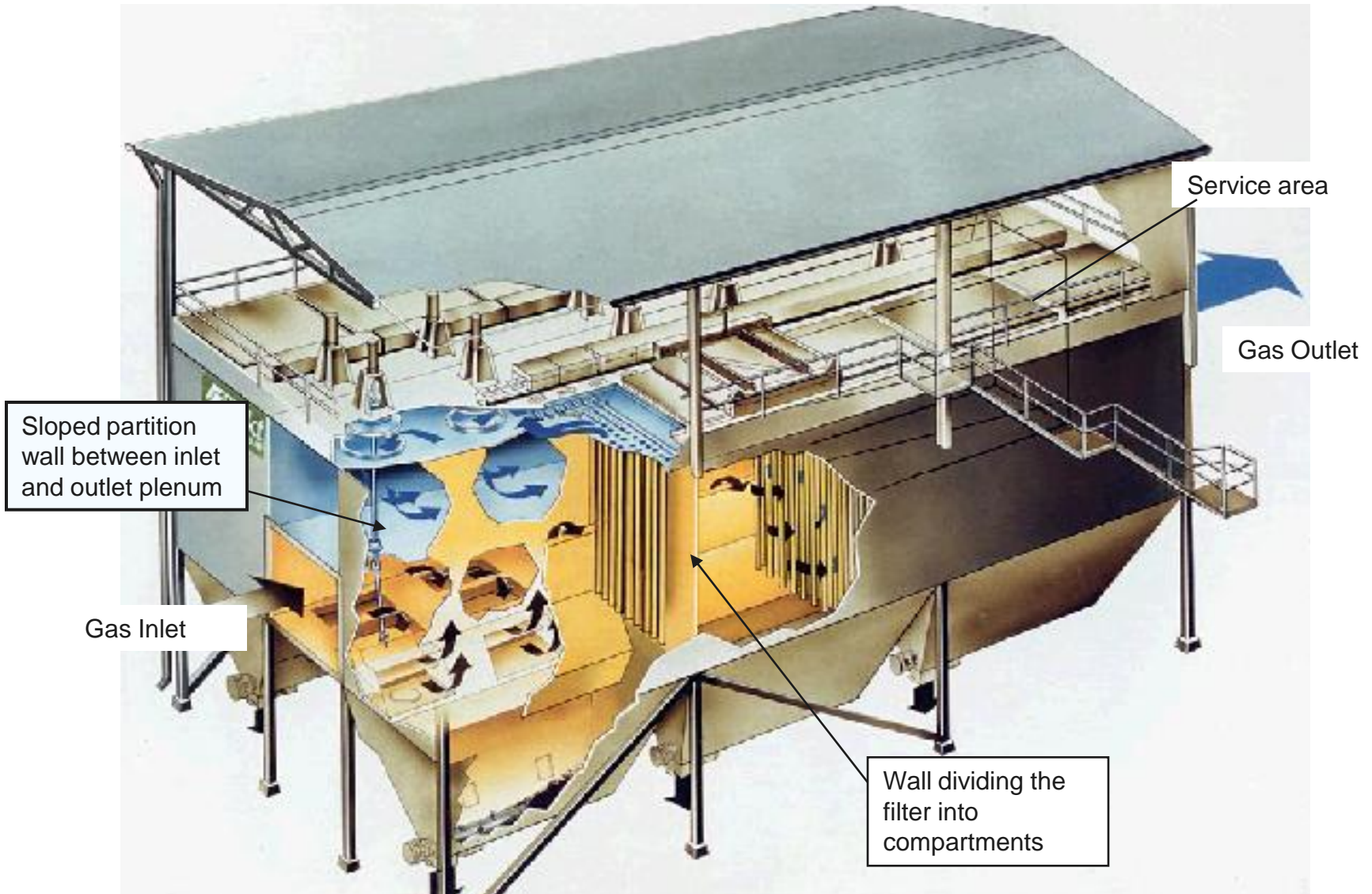


HRFF Design Issues

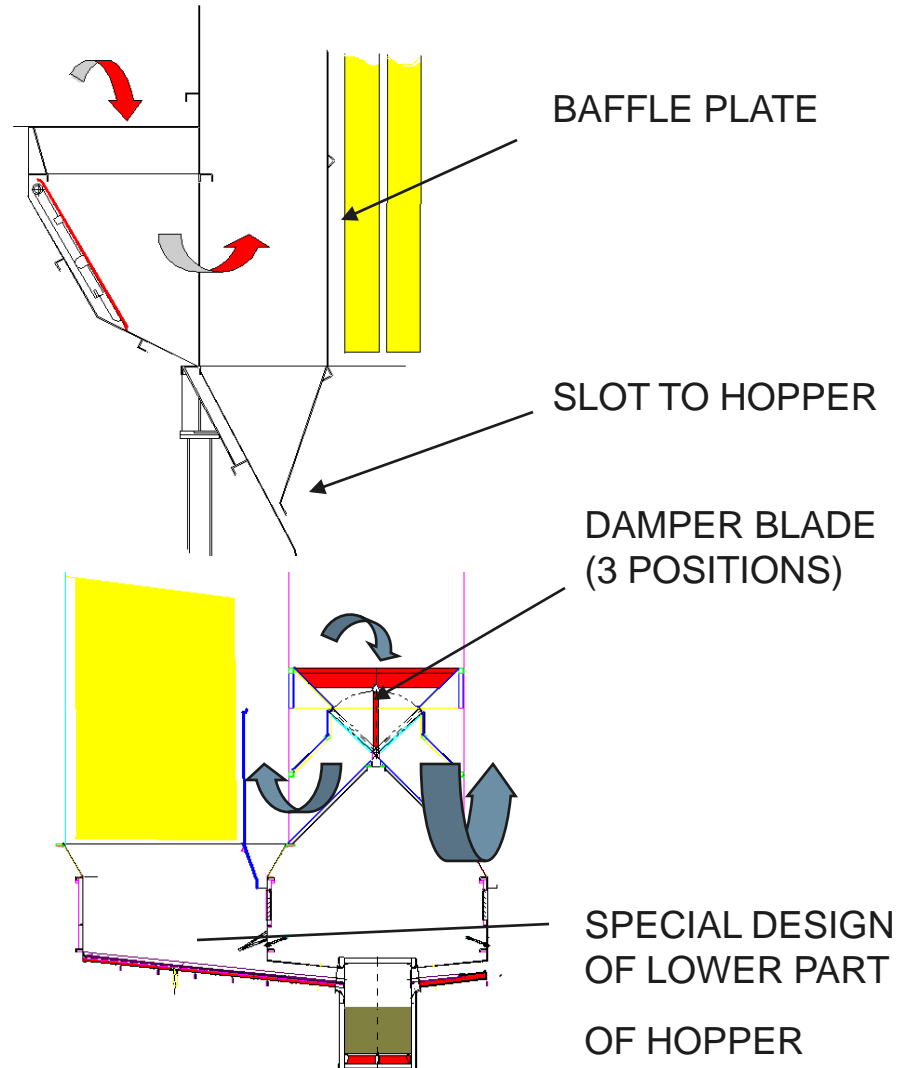
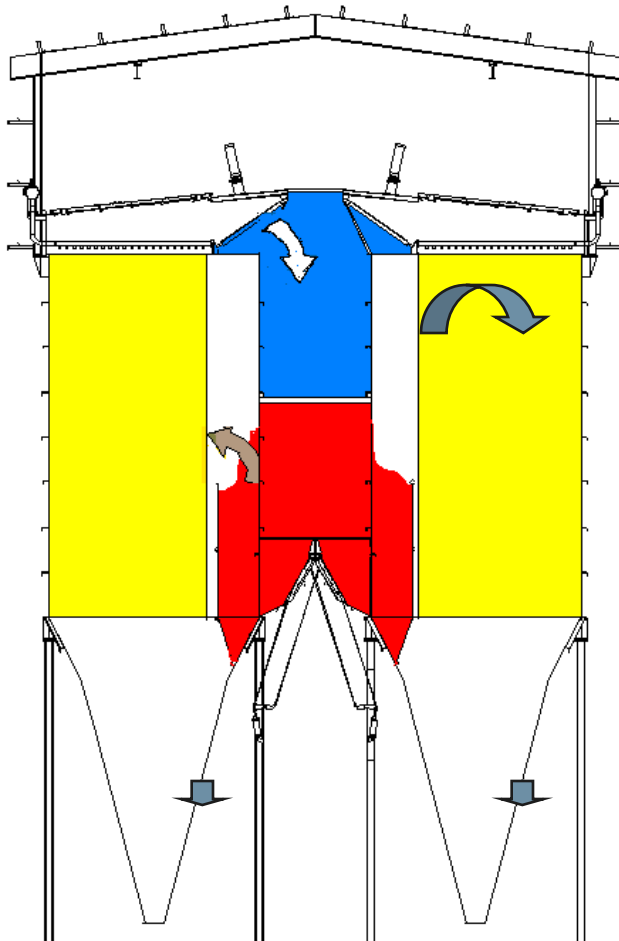
- Not effected by ash resistivity (gas temperature)
- Removal efficiency does not have a major impact on size
- Emissions nominally < 2.5 microns in diameter
- Capable of very efficient collection of SO₂ and Hg
- Smaller space requirements than LRFF and ESP for high volume, difficult ash applications
- Lower total installed cost compared to LRFF and ESP
- Slightly Higher Operating Cost than LRFF and ESP (higher pressure loss)
- Slightly Higher Maintenance Cost than LRFF(more frequent bag changes) and ESP

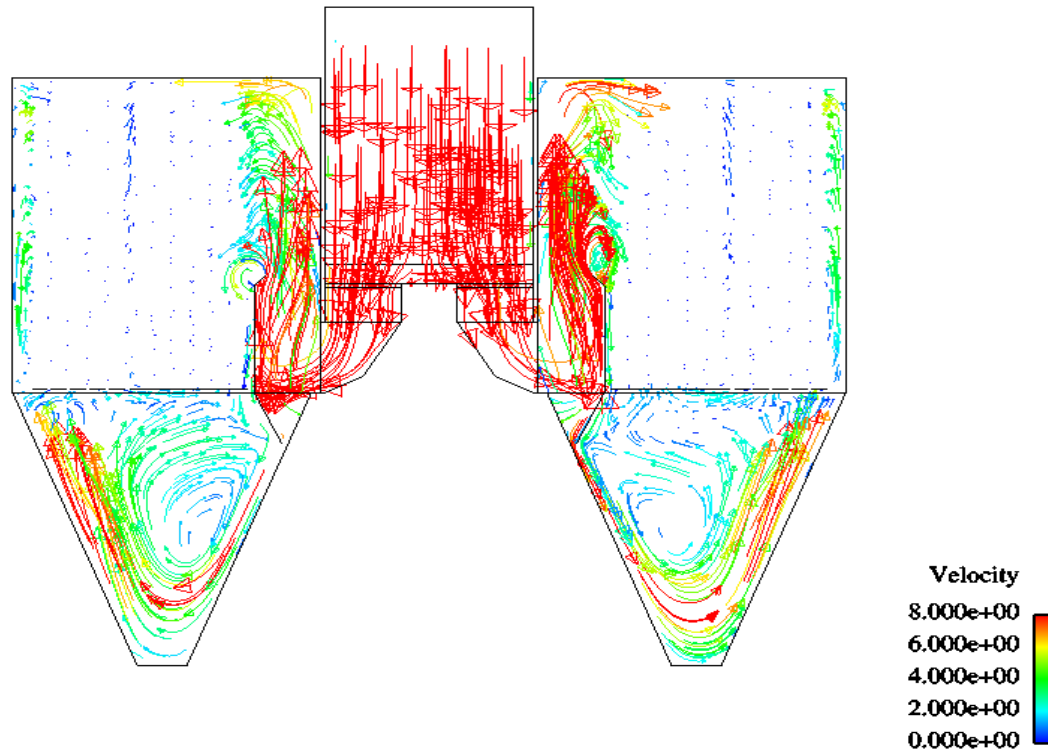


HRFF Design



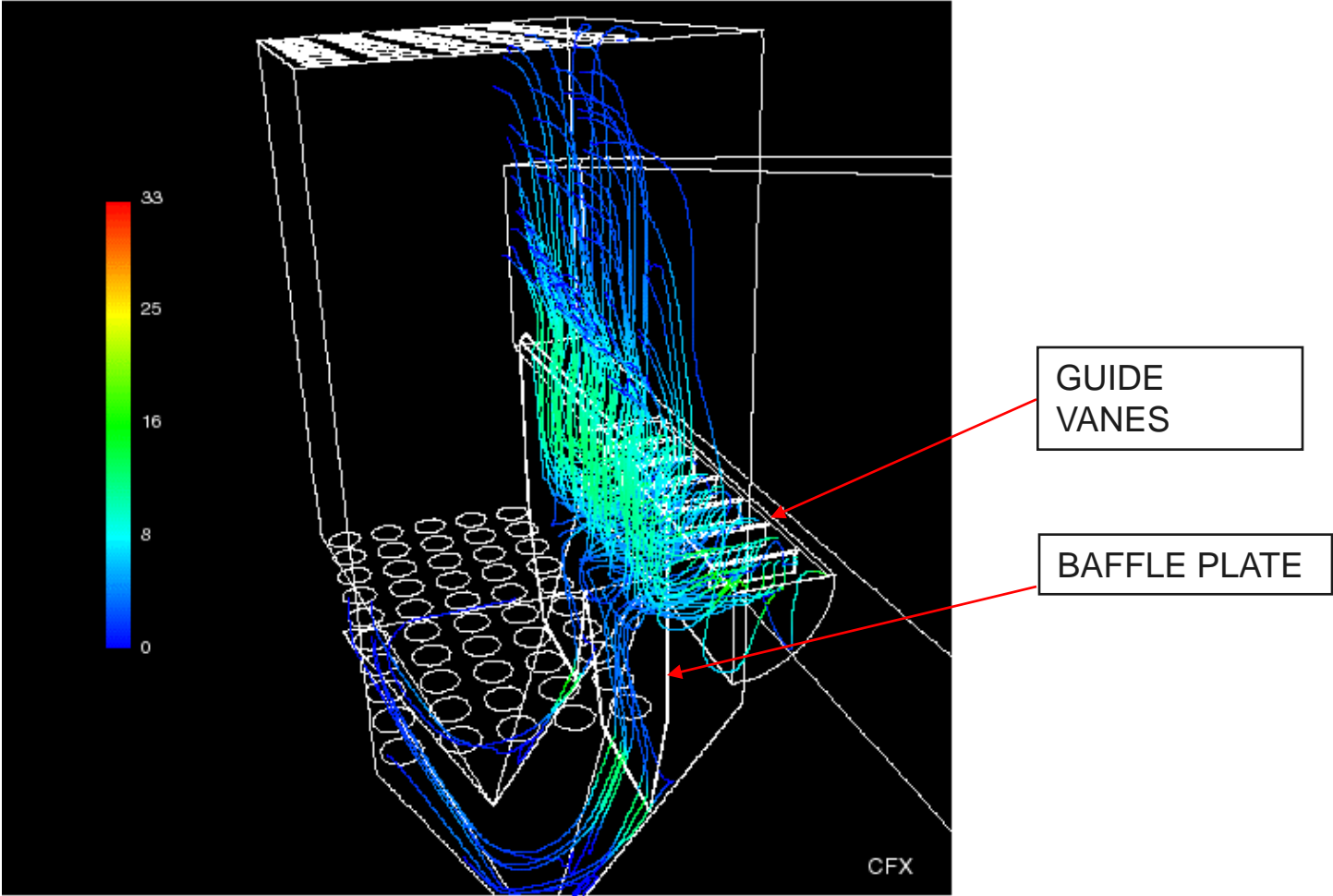
HRFF Design



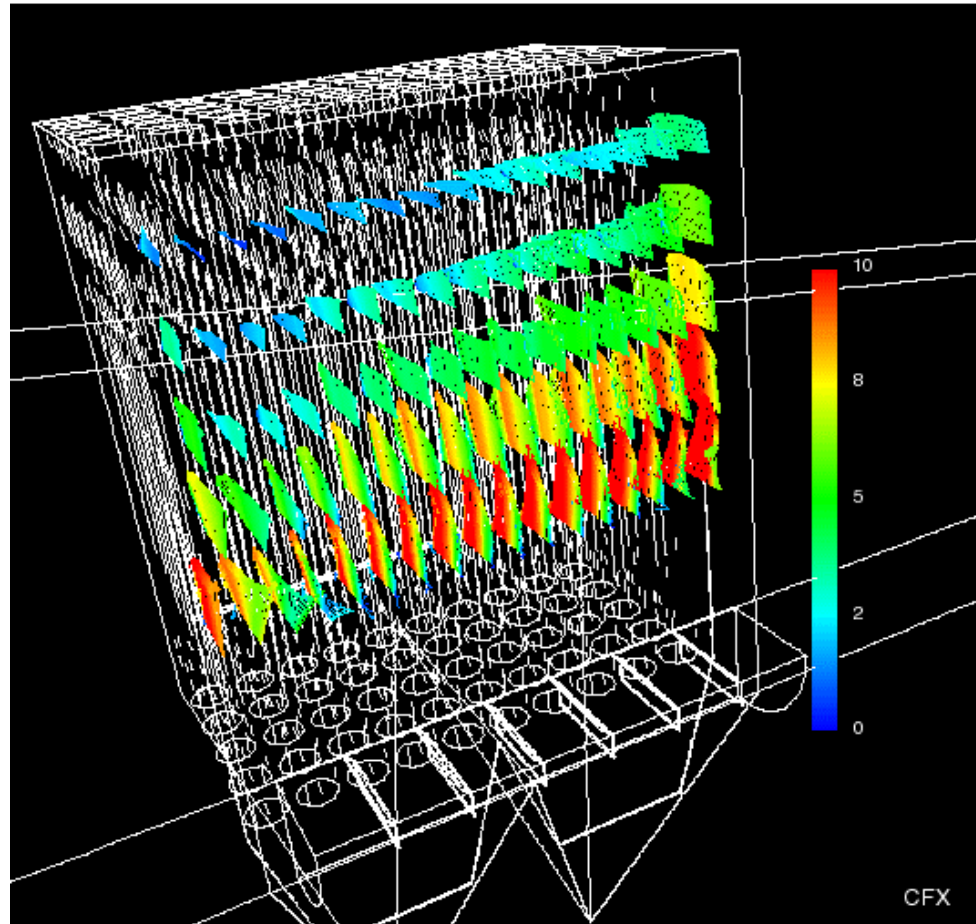


- Velocity profile, vectors [m/s]-

Fabric Filter Model Study



Fabric Filter Model Study



Fabric Filter Physical Model



Outlet duct (to fan)

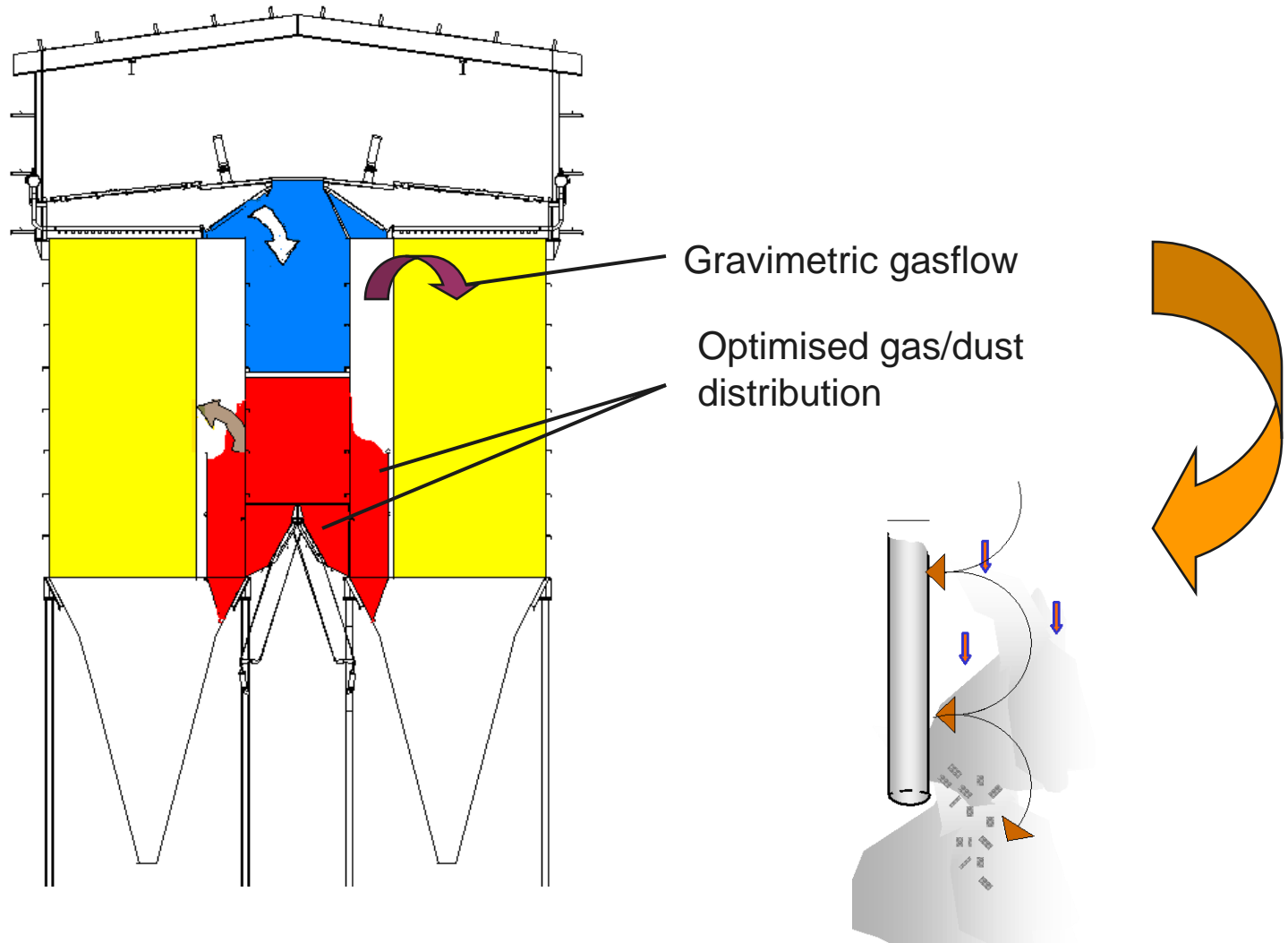
Venturi

Bypass duct (to fan)

Air inlet duct

Connection to fan system (2/3 of total flow bypass, half of filter built)

HRFF Design



Model Study Results, Gravimetric Flow

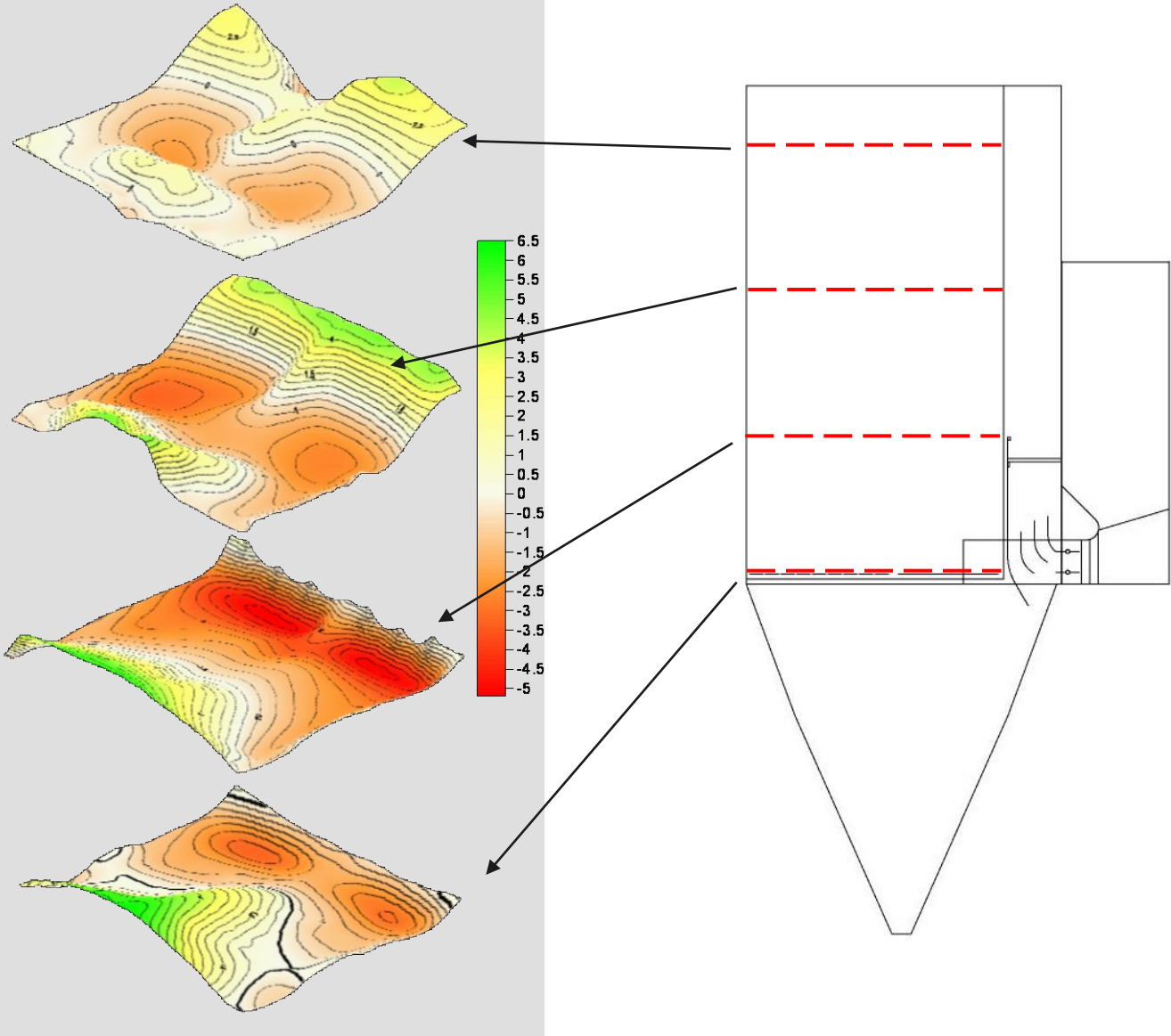


9 meters above bottom of filter bags

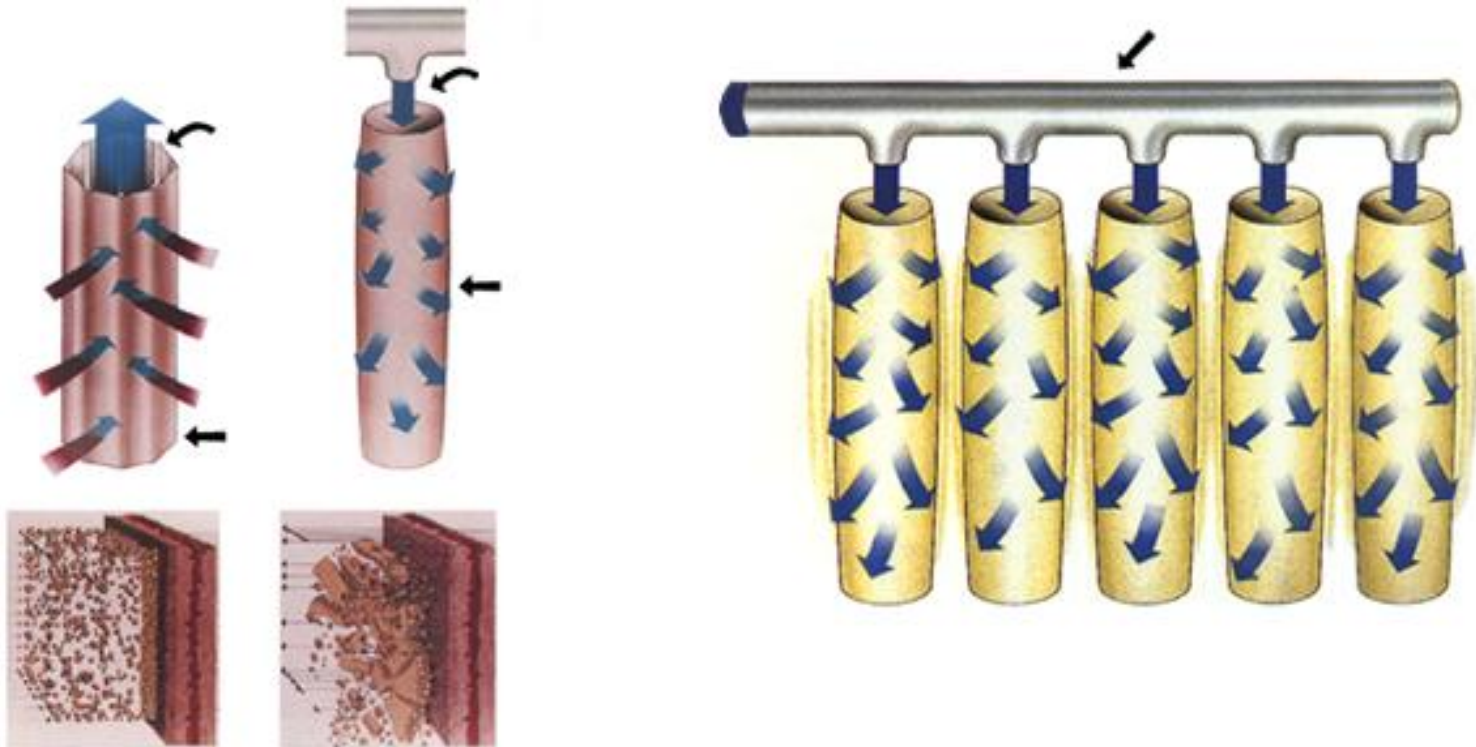
6 meters above bottom of filter bags

3 meters above bottom of filter bags

Bottom of filter bags



Cleaning Pulse Jet (High Ratio)



High ratio fabric filters use compressed air to clean the bags

HRFF Cleaning

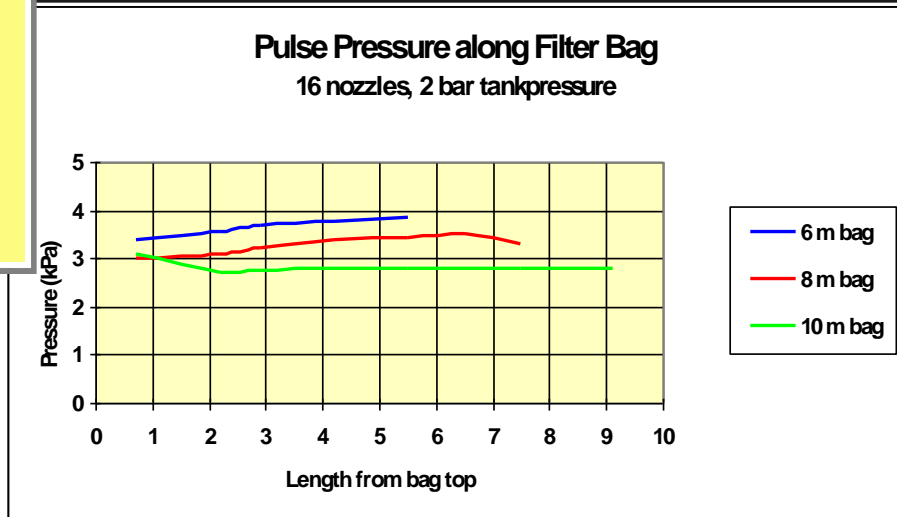
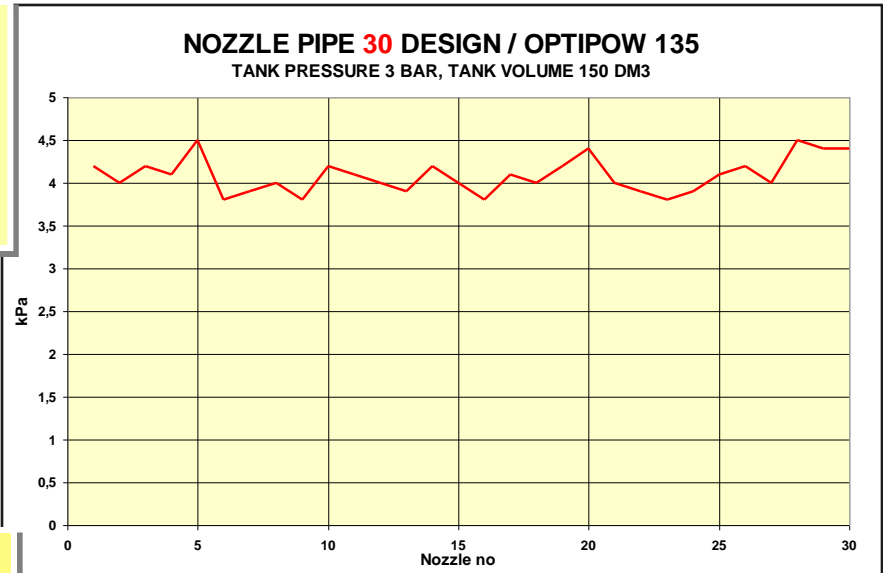
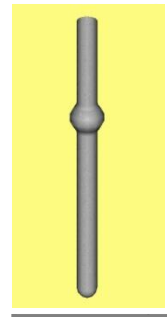
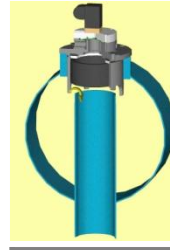
Cleaning Type	Pulse Pressure	Cage Type	Filter Bag Max Height	Issues
High Pressure / Low Volume	60 – 100 PSI	One Piece	19 ft	Housing Footprint
Intermediate Pressure, Intermediate Volume	25 – 50 PSI	Multi-piece cage	33ft	Cage Wear Penthouse Restrictions
Low Pressure / High Volume	< 15 PSI	Multi-piece cage	26ft	Cage Wear Penthouse Restrictions

Pulse Cleaning System

Intermediate Pressure / Intermediate Volume

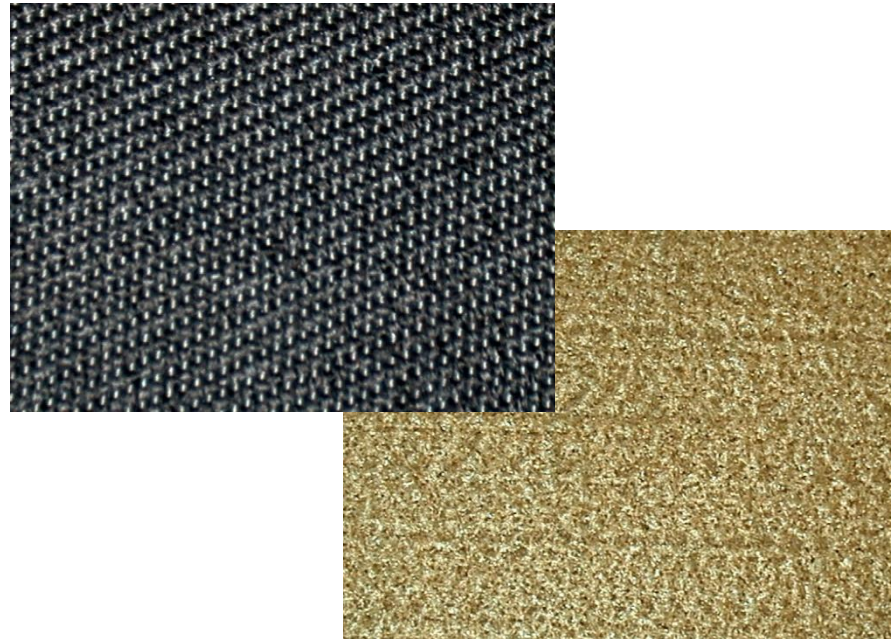
High efficiency pulse

- large area system gives minimum pressure losses
- several long bags cleaned with one valve
- quick, sharp pulse gives high acceleration to bag/dust layer
- equal cleaning pulse to all bags in a row (standard up to 30 bags)
- equal cleaning effect along the whole bag length (up to 10 m)



- Needlefelts are the predominant fabrics used in high ratio filters
- Needlefelts are non-woven fabrics manufactured by the mechanical entanglement of fibres using needlepunching equipment
- Each of the media have limitations on temperature, acid, alkali, hydrolisis, oxidation and abrasion resistance

- Pristyne™ Membrane by W. L. Gore & Associates, Inc.
- Polyester
- Fiberglass
- Aramid
- Polypropylene
- PPS
- P-84®
- Teflon® /PTFE
- Acrylic
- Blended Fibers



Proper media selection is best made considering the following criteria:

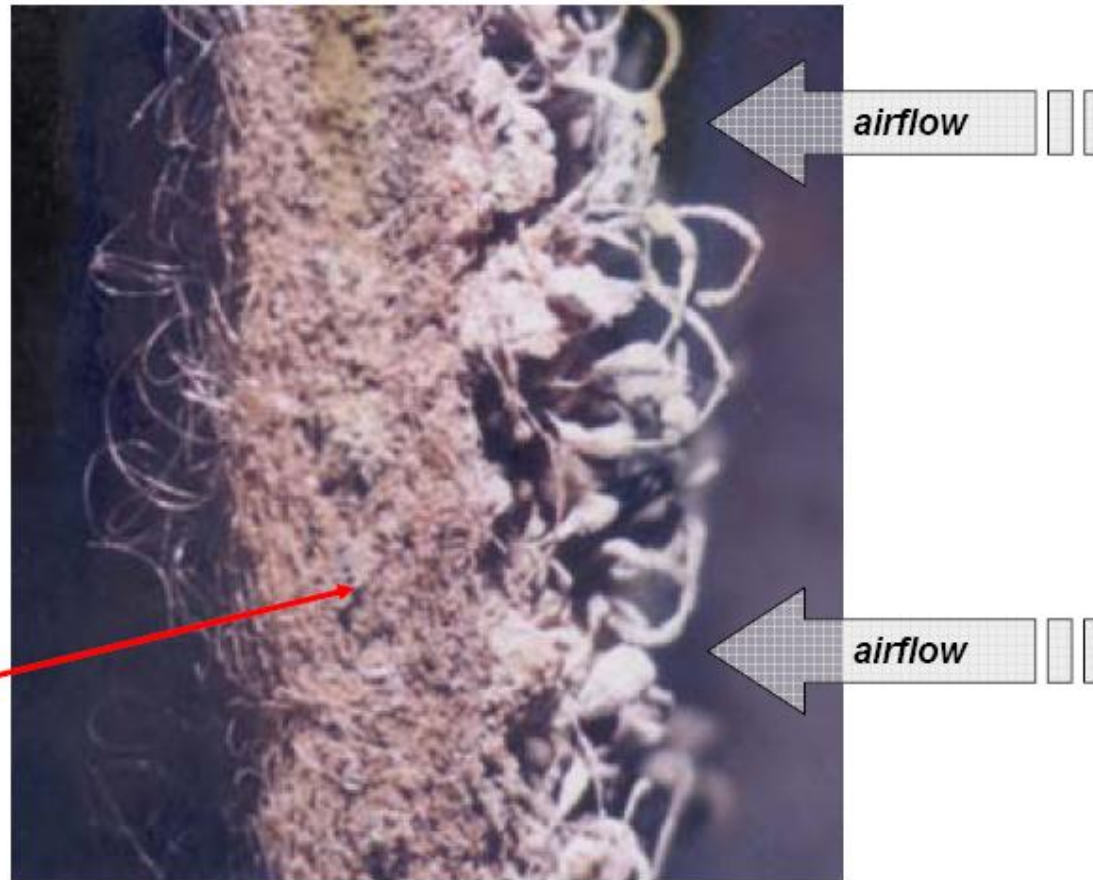
- Temperature
- Application
- Chemistry of gas stream
- Type of cleaning employed
- Moisture of gas stream
- Abrasiveness of dust
- Past experience

- Generally speaking, felts are used in HRFFs and wovens are used in LRFFs.

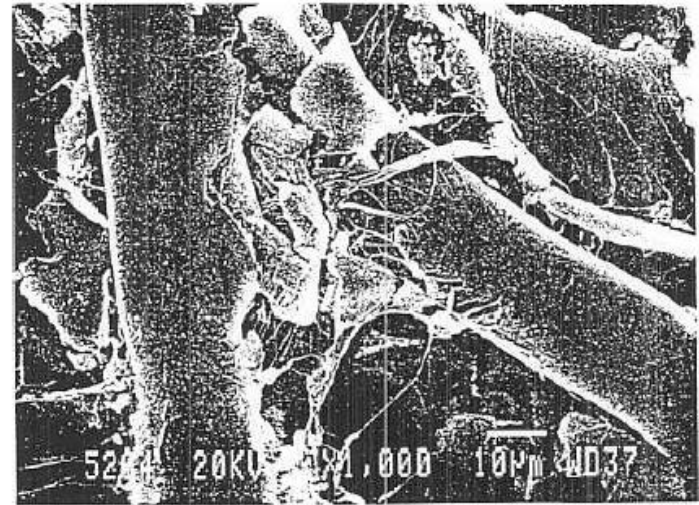
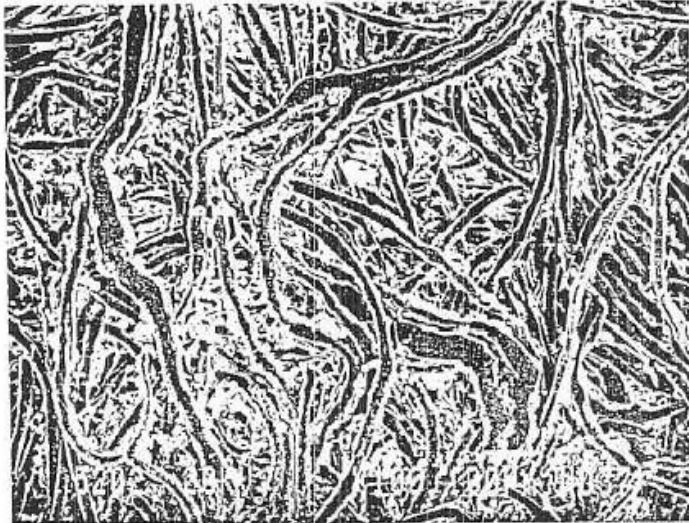
- Construction and quality of the filter media, and the bag confectioning quality, are of paramount importance for the FF dust emission, pressure drop, and bag life performance.
- A bag life warranty guarantee today is typically equal to or greater than 4 years / 32,000 hrs.
- The service life of filter bags is determined by the onset of mechanical failure due to too low mechanical strength, loss of performance in terms of excessive dust emission or pressure drop over the bags.
- Technical quality of the bags must be validated.
 - If the bag quality is not up to the specified process conditions and FF performance demands, the only remedy is normally to replace the bags.
 - Replacing the bags is costly and time consuming and can result in loss of production for the customer.

A conventional filter bag collects particulate in the depth of the fabric.

Dust gets trapped in the fabric



Cross section view – standard felt bag (used)



- The use of a PTFE Intrinsic Coating enhances surface filtration and early capture of fine dust particles.
- For the long-term filter media performance, it is very important to keep the dust on the surface of the felt and to prevent penetration of fine particles into the felt. This will give a slower rate of pressure drop increase over the bags and hence a longer bag life from pressure drop point of view.
- Overall gravimetric dust emission will also be reduced. The PTFE Intrinsic Coating also gives a slicker surface of the felt, hence enhancing dust release at cleaning of the bags.

Selection of Filter Media - Material Summary

- The most important criterion for filter media selection is the flue gas temperature, continuous and peak.
 - Heat degrades fibers at different rates for different fiber materials.
 - The key property for high temperature resistant fibers is their continuous operating temperature limit.
 - Fibers can survive short term exposure to temperatures above their continuous operating temperature limit, but the high heat will degrade the fiber.
 - This degradation has the effect of reducing the strength properties of the fiber, and hence reducing the mechanical bag life of the filter media.
- Chemical exposure, such as contacts with acids and alkalis, can have a is also an important consideration.
 - Each type of fabric and fiber has its particular susceptibility to chemical attack. Common to synthetic polymer fibers is however the strong acceleration of the degradation with the temperature. An often applicable rule of thumb is; 10 °C (18 °F) higher temperature implies a doubling in degradation rate.

Filter Media - Material Summary



Filter media summary						
Material	PES	PAC	PPS	PI	PTFE	GLS
Polymer (Common Trade Name)	Polyester	Dolanit Ricem	Ryton Procon Torcon	P84	Teflon	Fibreglass
Temperature degF						
Continuous	275	257	347	392	464	464
Peak	302	266	392	500	500	536
Resistance						
Acid	3	4	4	3	5	4
Alkali	2	3	4	3	5	3
Hydrolysis (H2O)	2	4-5	5	3	5	5
Oxidation (O2)	5	3	3	3-4	5	5
Abrasion	5	3-4	3-4	4	3	1
Price rel. to PES	1	1.5	3.5	6.5	15	2.5

1 = Bad, 2 = Mediocre, 3 = Generally good, 4 = Good, 5 = Excellent

FF Start-up and Shut-down Procedures



Inlet High Temperature and Erosion



Temperature & Erosion



- Fabric Filters have been used for many years for particulate collection
- Design details are very important to achieve maximum performance
- There are opportunities for continuous improvements
- When part of a DFGD system, highly efficient reduction of SO₂, SO₃, HCl, HF and particulate matter is achieved

Introduction

DFGD Overview

SDA Technology

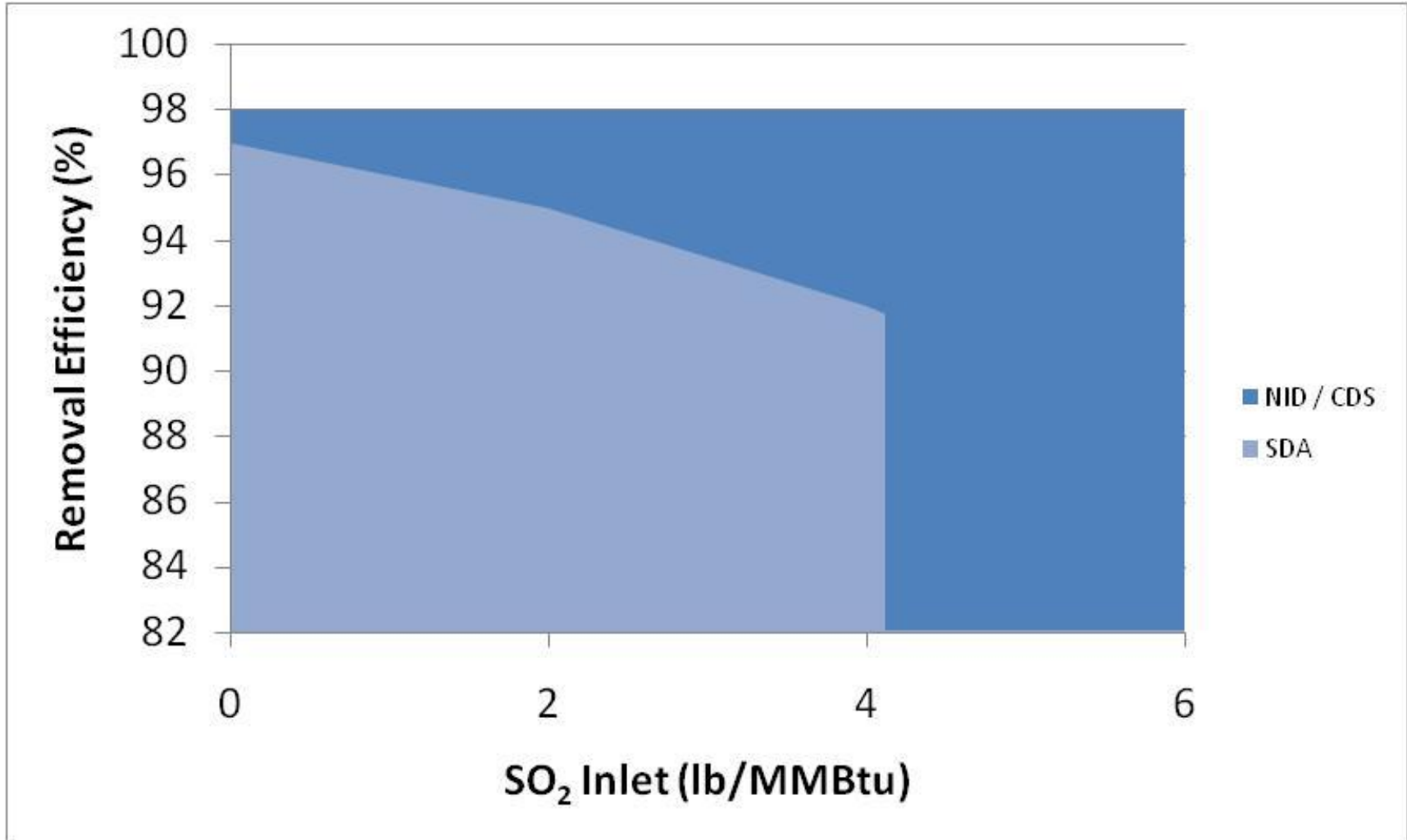
NID / CDS Technology

Fabric Filter Technology

Summary

FGD Technology Comparison




























Technology	SDA	NID / CDS
Design		
Absorber	Spray Dryer	J-Reactor / Fluidized Bed
Reagent	Lime	Lime
Reagent Preparation	Slaker	Hydrator
Byproduct	CaSO ₃ /CaSO ₄ /Ash	CaSO ₃ /CaSO ₄ /Ash
Performance		
Stoichiometric Ratio	1.2-1.8	1.2-1.8
Approach Temperature	30-35 °F	25-30 °F
L/G	0.03 gal/kacf	0.03 gal/kacf
Pressure Drop	11-13 in. w.g.	13-15 in. w.g.
SO ₂ Removal Eff.	95%	98%
SO ₂ Inlet (max)	2-3 lb/MMBtu	>5-6 lb/MMBtu



FGD Technology Comparison

-  Advantage
-  Neutral
-  Disdvantage



Technology Comparison	SDA	NID	CDS
Footprint			
Lime consumption			
Fuel flexibility			
System maintenance			
Pulverized coal installed base			
Erection cost			
Retrofit to existing fabric filter			
Turndown			
HAPS emissions			

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