



Topic :-

The Flue Gas Desulphurization (FGD) is a process of removal of sulphur dioxide (SO₂) from the flue gas.



Speaker :-

**Mr. Amrit Kumar Halder,
VP-Process & Proposal Utility Boilers & AQCS, ISGEC**

SO₂ Control Options for Indian Power Plants

**-Amrit Kumar Halder
CEE 3rd National Power-Gen
Environment Excellence Summit &
Awards 2024
27.06.2024**

Sr. No.	Agenda Description
1.	Introduction and Key Regulatory Drivers
2.	Technology Availability
3.	Overview of Wet FGD Technology
4.	Overview of Semi Dry FGD Technology
5.	Overview of Dry Sorbent Injection Technology
6.	Technology Suitability for Indian Thermal Power Plants

The Flue Gas Desulphurization (FGD) is a process of removal of sulphur dioxide (SO₂) from the flue gas.

NEED FOR FGD

- Combustion of fuel having sulphur results in SO₂ Emission
- Sulphur content in Indian coal ranges from 0.25 to 0.5 % and in imported coal it is more than 0.6 %.
- Coal with 0.5 % sulphur, generates SO₂ of range 1500 -2000 mg/Nm³
- SO₂ emission results in Acid-rain, corrosion of buildings & structures and affect human health

Key Regulatory Drivers: Indian Power Plants



Pollutant	Unit*	TPPs installed before December 31, 2003	TPPs installed after 2003 to December 31, 2016	TPPs to be installed from January 1, 2017
SO _x	mg/Nm ³	600 (<500 MW) 200 (>=500 MW)	600 (<500 MW) 200 (>=500 MW)	100

The above mentioned norms were introduced in Dec 2015 before which the SO₂ emission was governed by Chimney Height

*Corresponding to 6% O₂ Dry Volume.

NDA: Non-degraded Airshed, DA: Degraded Airshed (Poor Air Quality)



Wet FGD

- Under Collaboration and Technology Transfer Agreement with BPE for Units > 100 MW



Semi Dry FGD

- Under Licensing Agreement with Sumitomo SHI FW for Units > 50 MW
- First Unit has been commissioned @ Hindalco Mahan



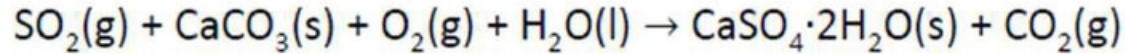
DSI

- Collaboration Agreement with United Conveyor Corporation (UCC).
- Secured orders from State Utilities like Mahagenco and WBPDCI for 6 Units of 210 MW each.

Wet FGD Technology Overview



- Overall Chemistry



- Single Loop Open Spray Tower Design
- Efficient use of reagents
- High chlorine designs
- Bidirectional nozzles installed
- Wider-angle spray cone ensures efficient spray pattern in spray zone
- Increase gas – liquid collisions
- Dual direction allows for complete coverage
- Over 12 GWs in operation
- Industry leading removal efficiency
- Greater than 99%



Wet FGD Technology Overview – Key Design Features



- >20 units: ~12,000 MW
- Open spray tower
- Dual spray nozzles and wall rings technology
- High (>99%) SO₂ removal producing wallboard grade gypsum
- High Reliability: >99%



Wet FGD Technology Overview – Key Design Features

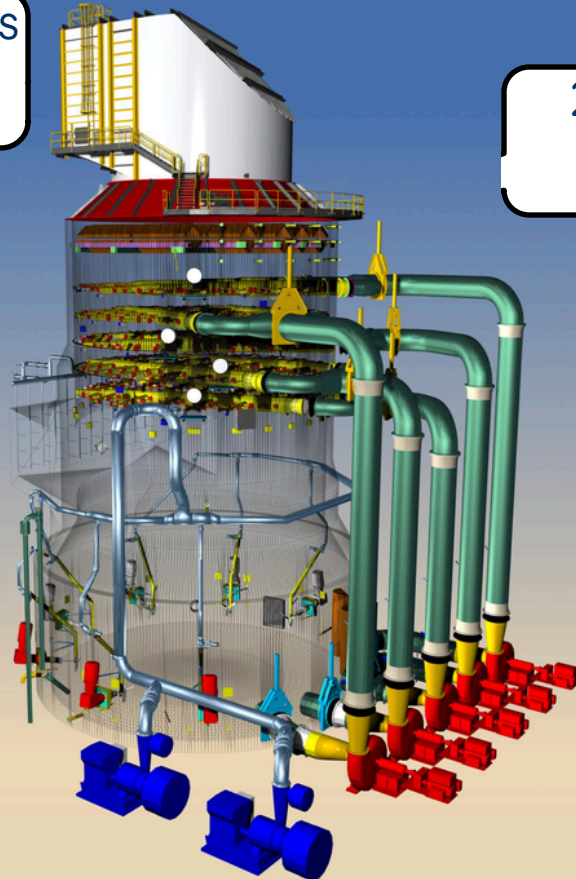


Bi-Directional Spray Nozzles

2-Stage Internal Mist Eliminator

Absorber Inlet and Inlet Awning

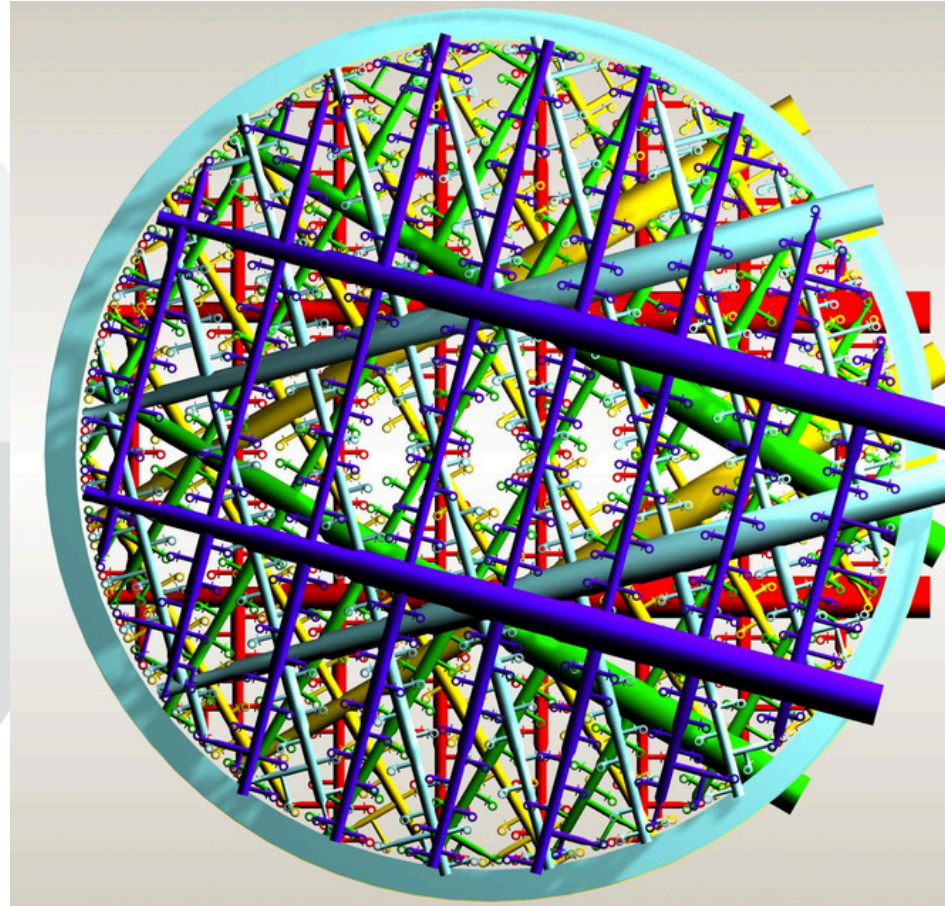
Reaction Tank forced oxidation with agitator



Absorber Design Greater Than 500 MW

Experience with Designing Systems to Treat Flue Gas from Multiple Units

Spray nozzles and piping arranged to minimize vertical alignment of nozzles and maximize spray pattern coverage

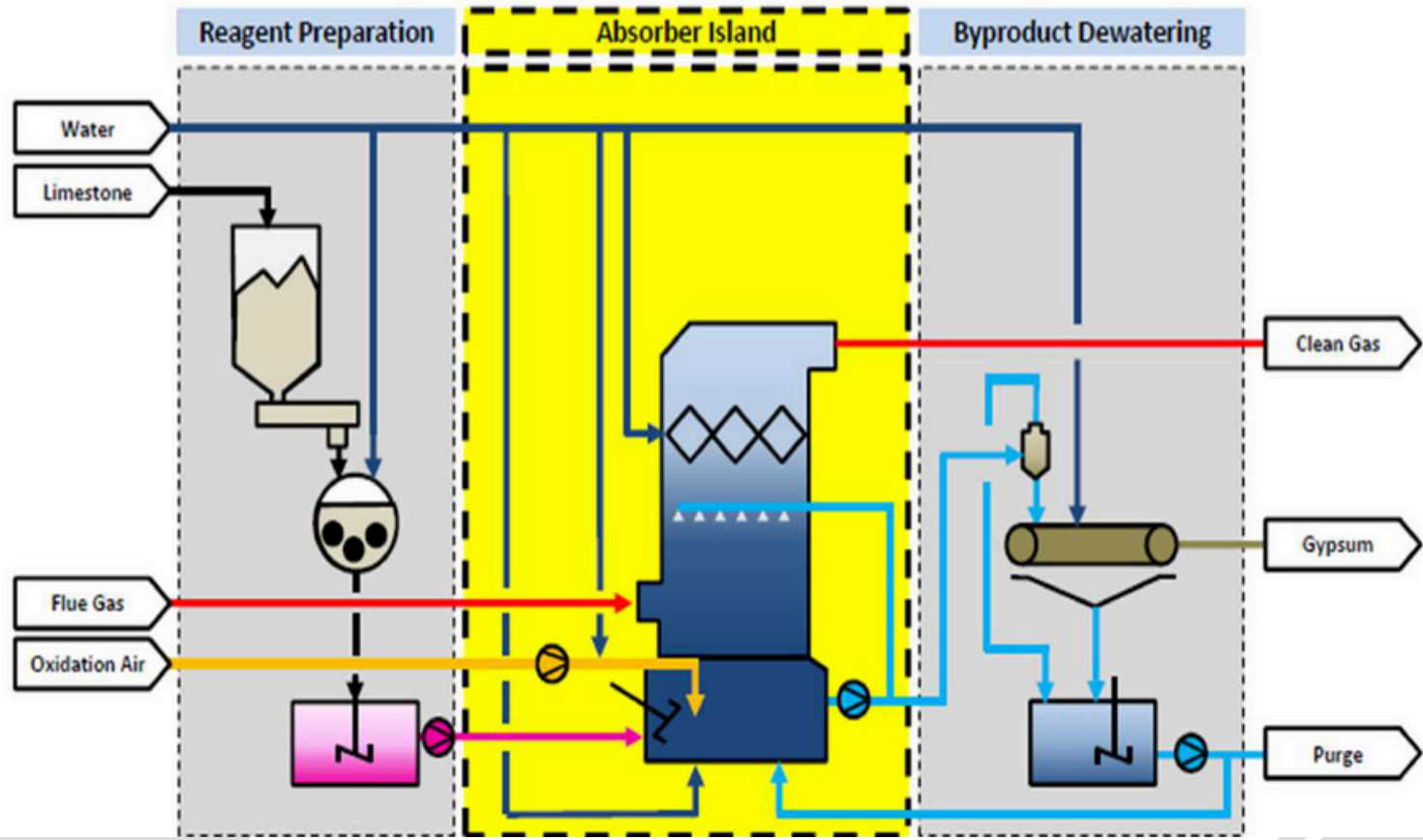


- Spray Level 1
- Spray Level 2
- Spray Level 3
- Spray Level 4
- Spray Level 5

- SO₂ reduction
- Reagent consumption
- Gypsum oxidation and quality
- Pressure drop
- Water consumption
- Turndown
- Power consumption
- Availability



Wet FGD Process – Simple Schematic



Wet FGD – Babcock Power Project References



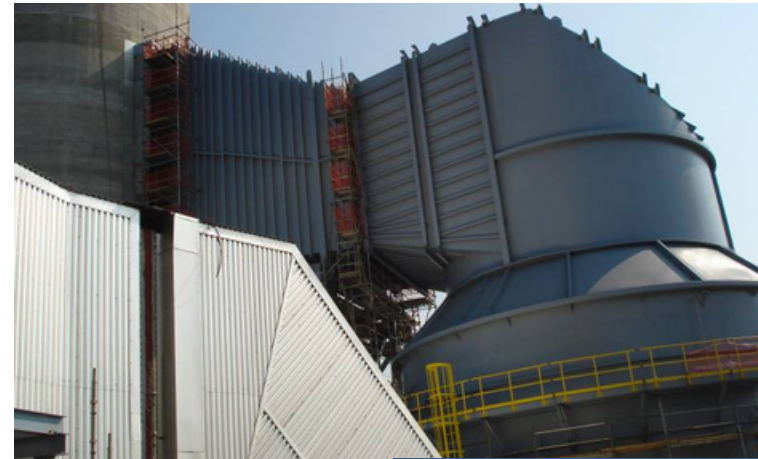
Luminant
Oak Grove Unit 1
Robertson County, TX

SIZE OF UNIT(S), MW	850
NUMBER OF ABSORBERS	1
FUEL TYPE	Lignite
FUEL SULFUR CONTENT, %	1.34
FLUE GAS FLOW, SCFM	2,284,454
REAGENT	Limestone
OXIDATION	Forced
END PRODUCT	Gypsum
SO ₂ REMOVAL	98.0
DATE OF START-UP	2010



SCE&G Wateree Units 1 & 2 Eastover, SC

SIZE OF UNIT(S), MW	700
NUMBER OF ABSORBERS	1
FUEL TYPE	Bituminous
FUEL SULFUR CONTENT, %	2.00
FLUE GAS FLOW, SCFM	1,735,568
REAGENT	Limestone
OXIDATION	Forced
END PRODUCT	Gypsum
SO ₂ REMOVAL	98.0
DATE OF START-UP	2010



Wet FGD – Babcock Power Project References (Single Absorber for 3 Boiler Units)



LG&E-KU Brown Units 1, 2, & 3 Harrodsburg, KY

SIZE OF UNIT(S), MW	750
NUMBER OF ABSORBERS	1
FUEL TYPE	Bituminous
FUEL SULFUR CONTENT, %	3.80
FLUE GAS FLOW, SCFM	1,971,997
REAGENT	Limestone
OXIDATION	Forced
END PRODUCT	Gypsum
SO ₂ REMOVAL*	98.0
DATE OF START-UP	2010



Wet FGD – Babcock Power Project References (Single Absorber for 2 Boiler Units)



LG&E-KU Mill Creek 1&2 Louisville, KY

SIZE OF UNIT, MW	660
NUMBER OF ABSORBERS	1
FUEL TYPE	Bituminous
FUEL SULFUR CONTENT, %	3.5
FLUE GAS FLOW, SCFM	1,671,590
REAGENT	Limestone
OXIDATION	Forced
END PRODUCT	Gypsum
SO ₂ REMOVAL*	98.5
DATE OF START-UP	2015



Isgec Wet FGD Reference – NTPC Kudgi – 3x800 MW Wet FGD on EPC Basis



Project: Kudgi Super Thermal Power Station Stage – I

Client: NTPC Limited

Capacity: 3 x 800 MW

Order Date: July 2018

Location: Kudgi, Karnataka

First 800 MW Wet FGD Unit commissioned in NTPC Kudgi in March 2024



Isgec Wet FGD Reference – NTPC Gadarwara – 2x800 MW Wet FGD on EPC Basis



Project: Gadarwara Super Thermal Power Station Stage – I

Client: NTPC Limited

Capacity: 2 x 800 MW

Order Date: September 2018

Location: Gadarwara, Madhya Pradesh



Isgec Wet FGD Reference – OPGC Jharsuguda – 2x660 MW Wet FGD on EPC Basis



Project: IB Valley TPS,
Banharpalli, Jharsuguda

Client: OPGC

Capacity: 2 x 660 MW

Order Date: December 2020

Location: Jharsuguda, Odisha



Isgec Wet FGD Reference – THDC Khurja – 2x660 MW Wet FGD – (Supply and Erection Contract)



Owner: THDC Khurja

Client: L&T- MHPS Boilers Privat Limited

Capacity: 2 x 660 MW

Order Date: August 2020

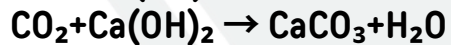
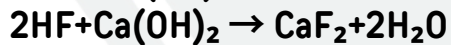
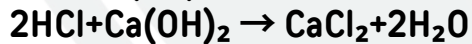
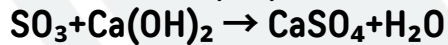
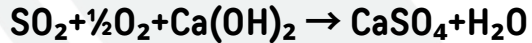
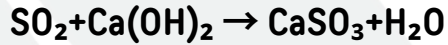
Location: Khurja, Uttar Pradesh



Semi Dry FGD Technology Overview

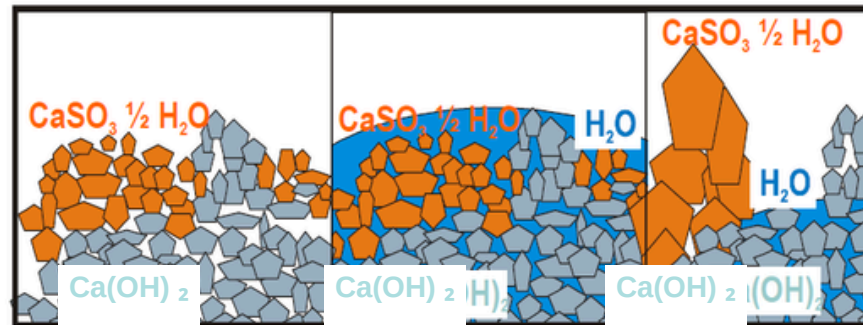


Chemistry



Formation of reaction products layer

ay



Reaction after first pass

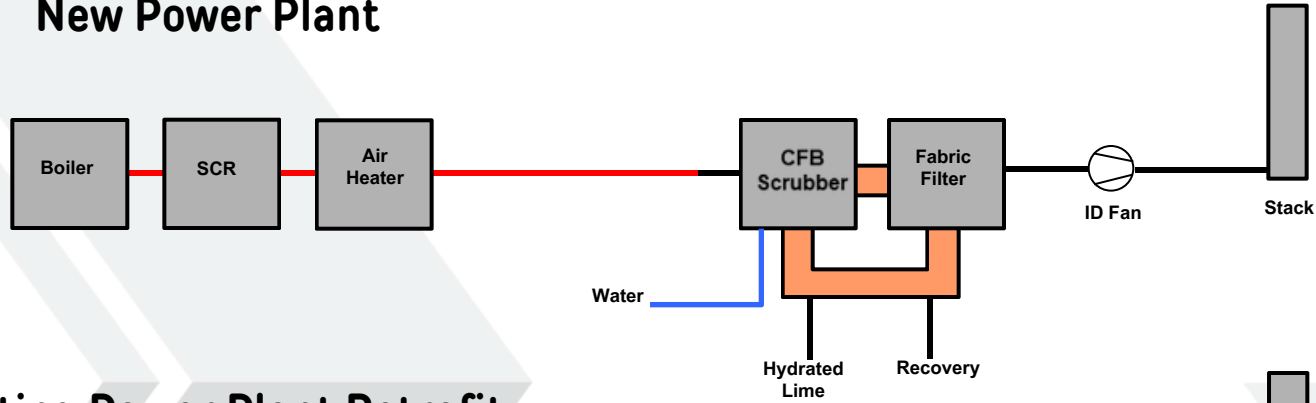
Water added to surface during fluidization

Sulfite crystal forms, exposing fresh surfaces

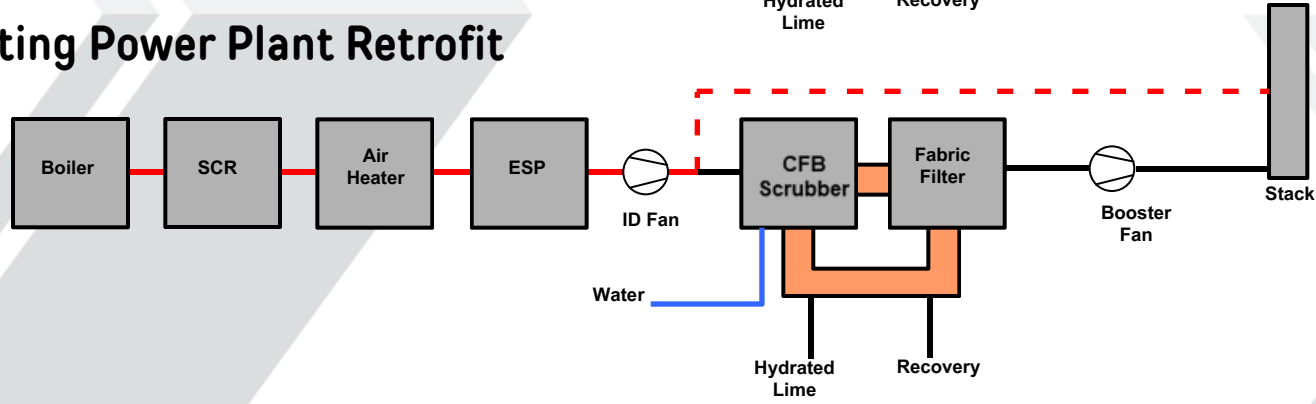
The reactions above take place in the dry desulphurization process in between the temperature range of 75 C – 145 C

Semi Dry FGD – Main Power Plant Scrubber Arrangement

New Power Plant



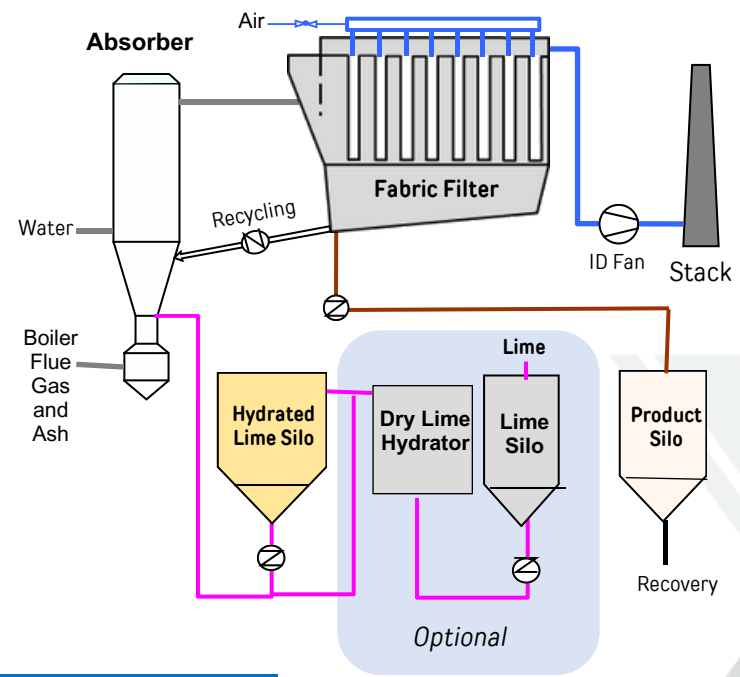
Existing Power Plant Retrofit



Circulating Fluidized Bed Scrubbing Technology

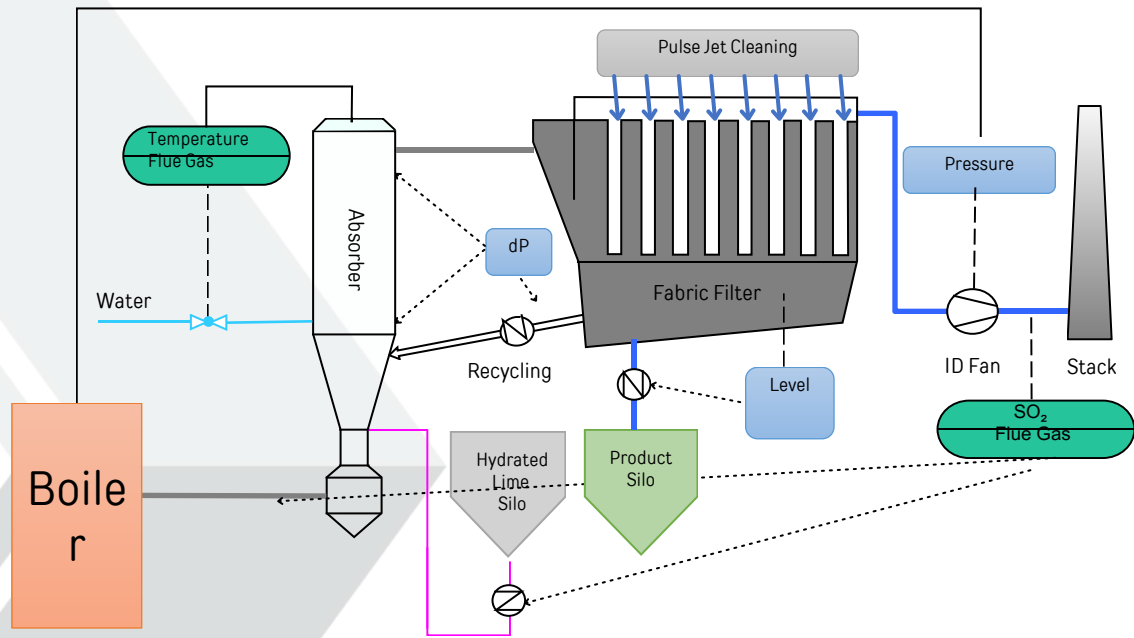
How does it work?

- Flue gas with fly ash enters the bottom of the absorber, flowing upward through venturi to accelerate the gas causing turbulent flow.
- Recycled solids, reagents 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. Over 60% of the solids are recycled over and over to the absorber.
- Reactive absorbents like sodium carbonates, hydrated lime, 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 (project economics dictate need for onsite hydrator)



• Flexible, reliable multi-pollutant capture with minimal water consumption

Scrubber Control Provides Widest Capture Range with Minimal Lime and Water- Fuel and Load Flexibility



- Independent water control *maintains* dry flue gas at optimum temperature
- Independent sorbent control maintains stack emissions with changing fuels (recycling rate is controlled independently from FGT)
- Level detection in hopper is by vibrating probe type

Our CFBS Achieves High Capture of Multiple Pollutants

Performance Range of our Scrubber References

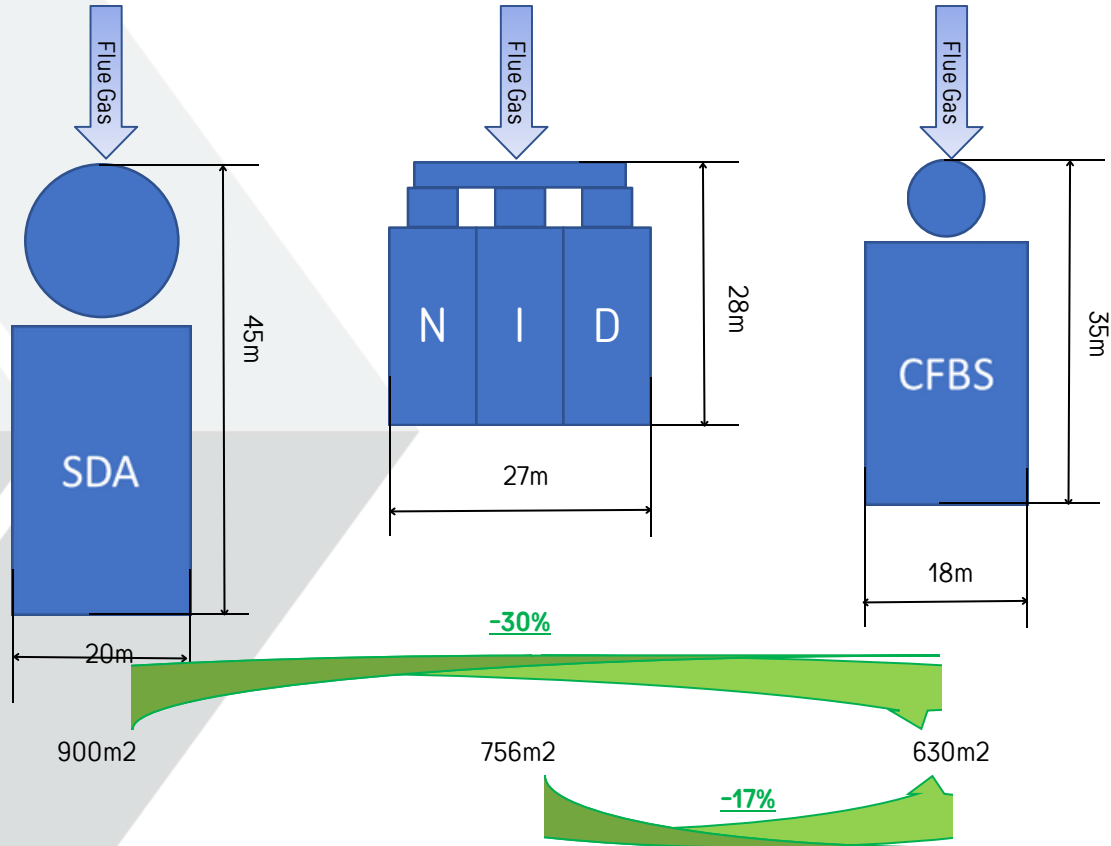


Pollutant	Stack Emission Level 6% O ₂ , Dry		Capture	Notes
	mg/Nm ³ *	ppmv		
PM	2 – 20	-	99-99.9%	With Fabric Filter
	20 - 50	-	99-99.9%	With ESP
SO ₂	10 – 200	3.5 – 75.1	85 - 99%	
SO ₃	10 - 50	3 - 15	90- 99%	Hydrated lime reacts with SO ₃ within CFBS much quicker than SO ₂ and it's captured 'first'.
HCl	1 – 10	0.7 – 6.6	95 - 99%	
HF	0.1 – 1	0.1 – 1.2	95 - 99%	
Total Hg (all forms)	0.003 – 0.050	0.36 – 6 ppbv	60 – 80%	Low halogen PRB coal
	0.001 – 0.035	0.12 – 4.2 ppbv	80 – 90%	With lignite coke injection
	0.001 – 0.030	0.12 – 3.6 ppbv	90 – 99%	With activated carbon injection
Total Dioxines, Furanes (all forms)	0.009 – 0.08 x 10 ⁻⁶	0.7 – 6.0 ppbv	95 – 98%	With activated carbon injection

* Normal Conditions = 20°C, 101.325 kPa, 24.94 Nm³/mol

Layout Comparison to other Semi Dry Systems

Example: 1x225 MWe

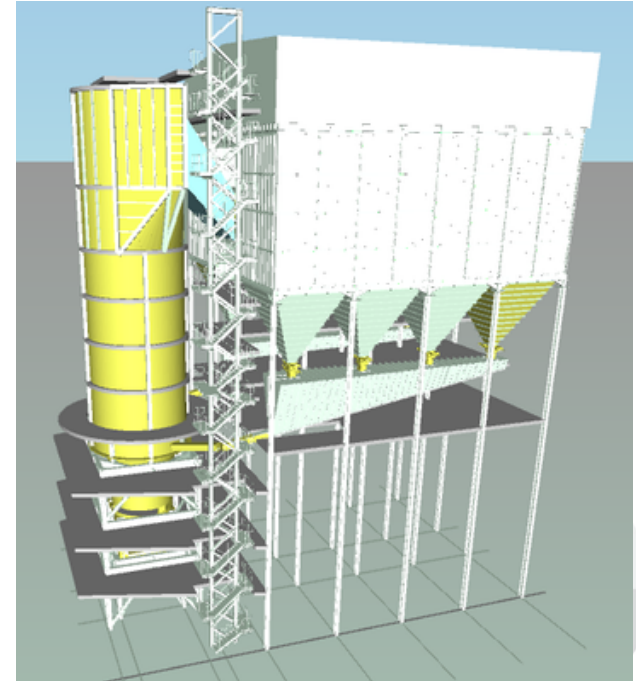


Hindalco CFB Scrubber Retrofit Project – Unit Configuration



1 x 150 MWe PC plant firing Indian coal (Unit #6)

- Plant Capacity: 6 x 150 MWe (presently FGD is being installed only at Unit #6)
 - Indian Coal with HHV 3400 - 3500 kcal/kg, ash content 36.2%- 39.1 & sulfur 0.32% - 0.52%
- Flue Gas Flow at CFBS Inlet (at Design Point) – 1,213,200 m³/h
- Sorbent: Hydrated lime quality of 82% Ca(OH)₂ at Design Point
- Plant FGD Configuration:
 - i. Flue Gas System including Scrubber, Fabric Filter, Gas Recirculation, Gas Bypass and Booster Fans - Unitized
 - ii. Process Water Storage System - Common for 6 Units
 - iii. Hydrated Lime Storage & Unloading System - Common for 2 Units
 - iv. Bi-Product Storage & Disposal System - Common for 2 Units
 - v. Instrument Air System - Common for 6 Units
 - vi. Electrical System - Common for 3 Units
- Layout: 1 Scrubber + 1 Fabric Filter for each unit
- Low pressure pulse jet Fabric Filter with full flow maintained with two (2) Fabric Filter compartments off-line
- Existing Chimney is being utilized without any modification (**no stack liner needed**)
- SO₂ Capture Efficiency at design point: 84%, corresponding to outlet emission of 480 mg/Nm³ at 6% O₂ dry Volume basis
- PM emission of 30 mg/Nm³ at 6% O₂ dry Volume basis



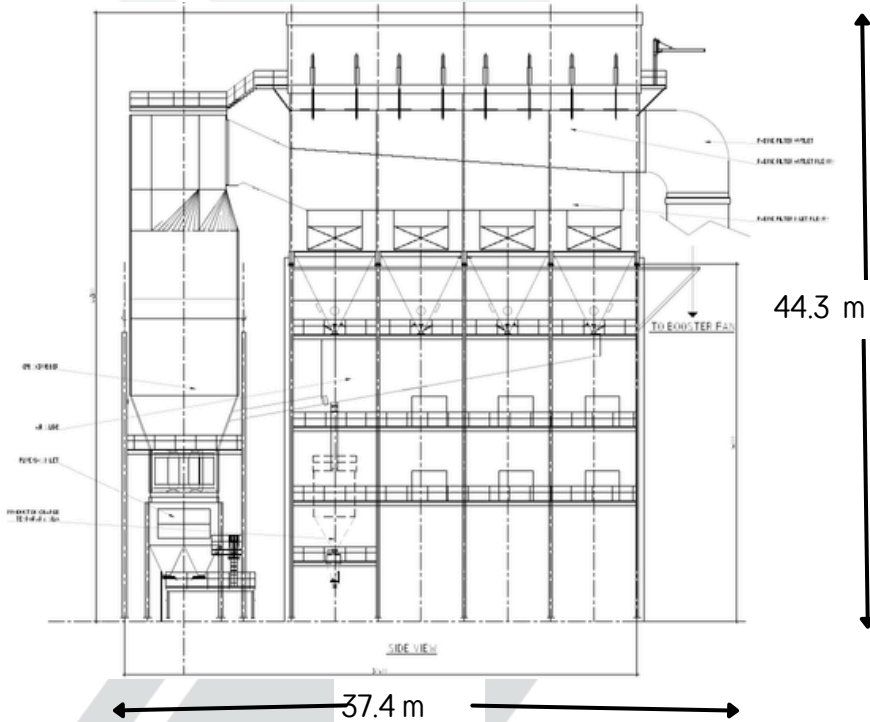
First Awarded Utility CFB Dry Scrubber Project in India

Hindalco Retrofit Project 1 x 150 MWe Plant CFBS System

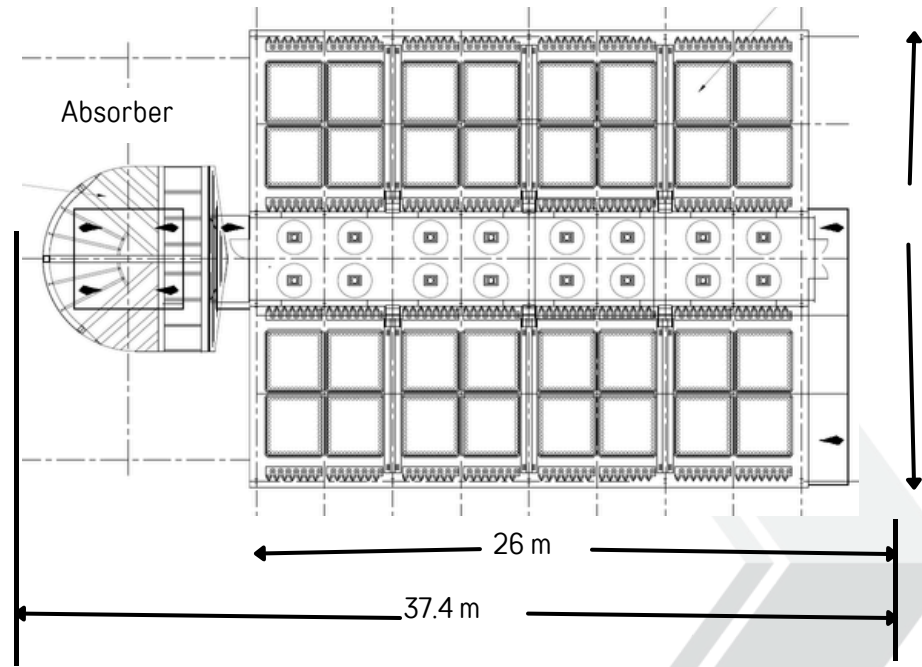


Absorber

Fabric Filter



Fabric Filter



Isgec SDFGD Reference – Successfully Commissioned recently

- First Semi Dry FGD commissioned by Isgec in India for Hindalco Industries Limited for 1x150 MW Unit at Mahan Aluminium CPP utilising Circulating Fluidised Bed Scrubber (CFBS) Technology of Sumitomo SHI FW.



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	Green	Red	Green
Low Water Consumption	Red	Green	Green
Fuel Flexibility (Fuel Sulfur Variability)	Green	Red	Green
Fine Particulate Capture	Red	Green	Green
High SO ₃ Capture Efficiency	Red	Green	Green
Mercury Capture	Red	Blue	Green
Compact System Footprint	Red	Blue	Green
Minimal Maintenance	Red	Blue	Green
Overall			Green

Advantage



Neutral



Disadvantage



World's Largest CFB Scrubber at Dry Fork PC Power Plant in USA

Cleaning the flue gas of 420 - 520 MWe PC boiler



- Plant Location: Gillette, Wyoming, USA
- Customer: Basin Electric Power Cooperative
- Plant Start-Up: 2011
- Plant Output: 420 MWe (520 MWe@SL)
- Fuel: PRB sub-bituminous coal
- Flue Gas Flow: 3,060,000 m3/hr
- Inlet Sulfur 350-2200 m3/hr
- Inlet Temperature 146 C, outlet 80 C
- Layout: 1 Absorber(13.4m Dia), 1 Fabric Filter

Stack Emission	SO2	SO3	HCl	Hg	PM
mg/dNm3 @ 6% O2	70	2	6	0.0025	15
ppmdv	25	0.6	3		
% capture	97	96	67	90	99.9

- Operating successfully for more than 10 years

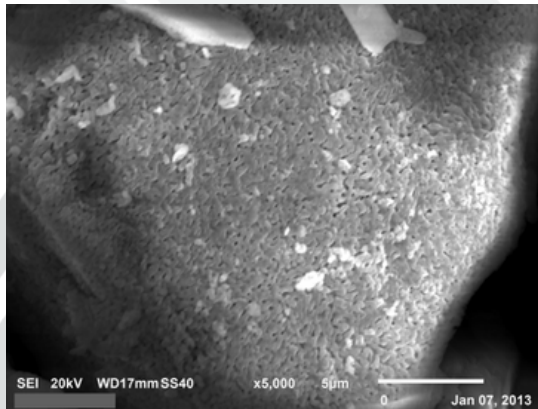


Dry Sorbent Injection (DSI) Technology Overview



Trona

- Use when:
 - Moderate to high SO₂ removal needed (approx. 50% to 90%)
 - Not available in all areas



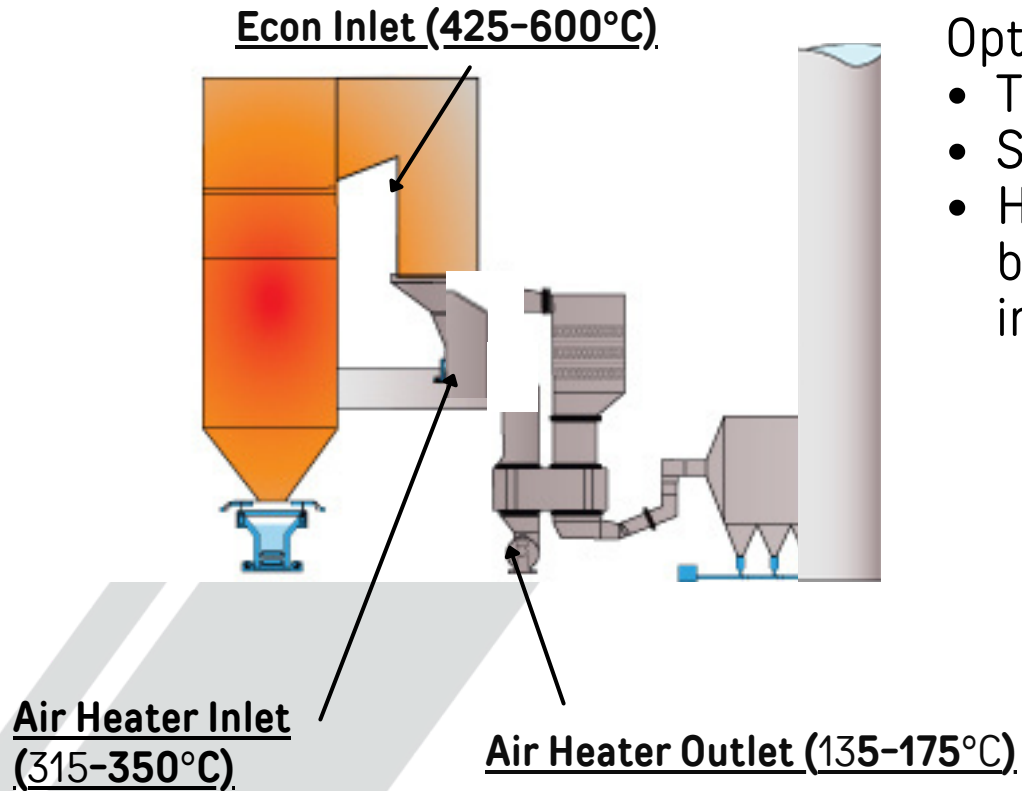
Sodium Bicarbonate

- Use when:
 - Moderate to High removals needed (50 to > 90%)
 - Want to minimize loading to ESP and/or ash removal systems

Hydrated Lime

- Use when:
 - Have fabric filter or large ESP
 - Low to moderate removals (30 to 70%)

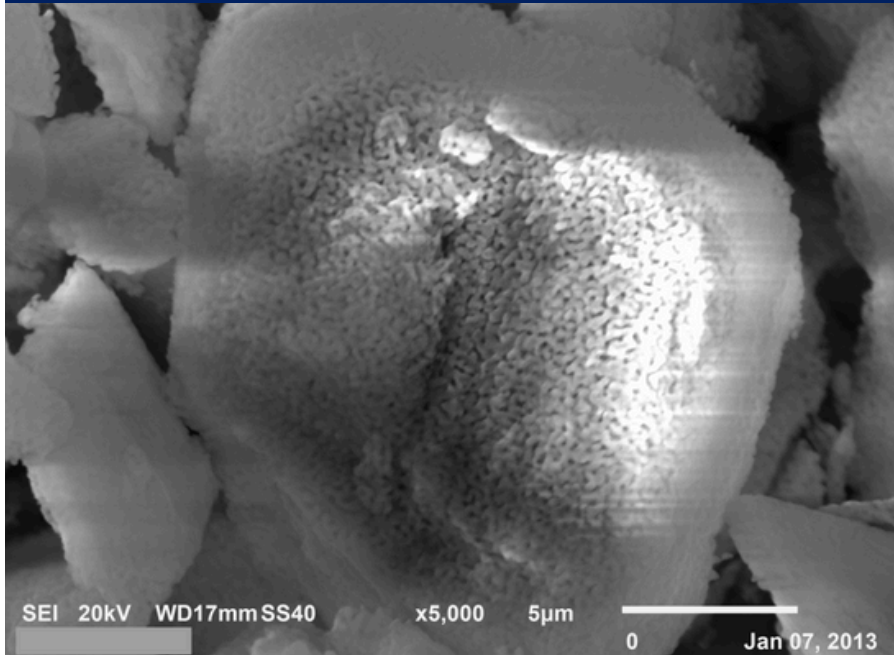
Dry Sorbent Injection Locations Temperature Effects



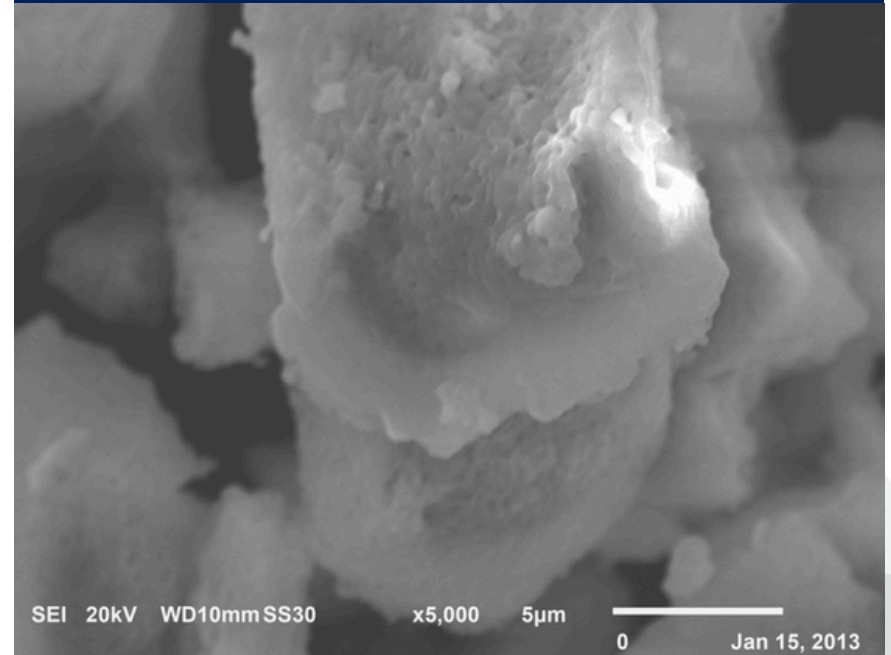
Optimum Temperature Ranges

- Trona – 150 to 535°C
- SBC – 150 to 345°C
- Hydrated Lime – 65 to 600°C, with best performance at air preheater inlet

SBC at 160 °C



SBC at 400 °C



Particles lose porosity at above 345C

DSI System – Typical PFD

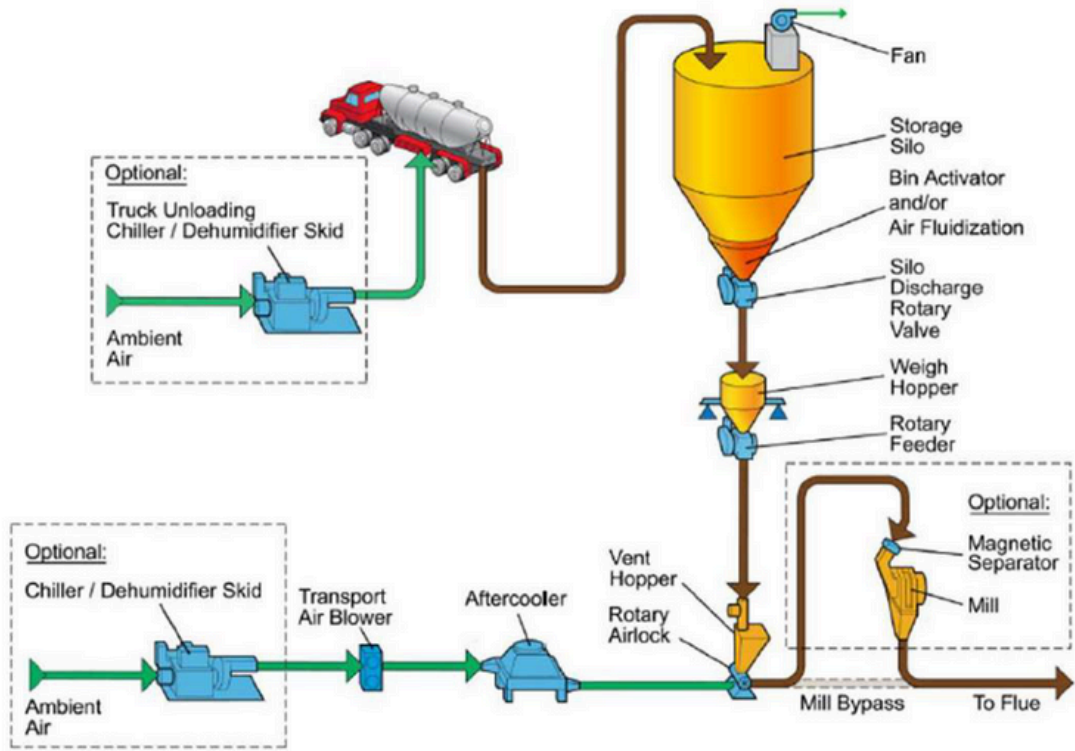


Figure 1. Typical DSI System Flow Diagram [9]

Calcination: $2(\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}) \rightarrow 3\text{Na}_2\text{CO}_3 + \text{CO}_2 + 5\text{H}_2\text{O}$

SO₂ Reaction: $\text{Na}_2\text{CO}_3 + \text{SO}_2 + \frac{1}{2} \text{O}_2 \rightarrow \text{Na}_2\text{SO}_4 + \text{CO}_2$

Sodium Bicarbonate

Calcination: $2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{CO}_2 + \text{H}_2\text{O}$

SO₂ Reaction: $\text{Na}_2\text{CO}_3 + \text{SO}_2 + \frac{1}{2} \text{O}_2 \rightarrow \text{Na}_2\text{SO}_4 + \text{CO}_2$

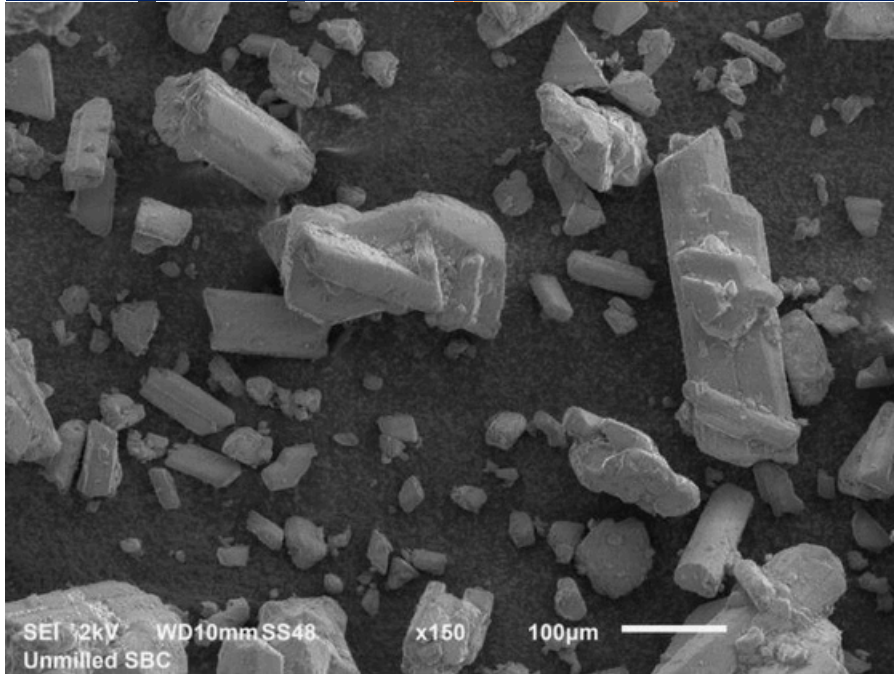
Hydrated Lime

- Greatest opportunity for increased performance is to reduce particle size
 - Increased surface area for reaction
 - Increased number of particles/collisions
 - Increased dispersion

UCC VIPER® Mill

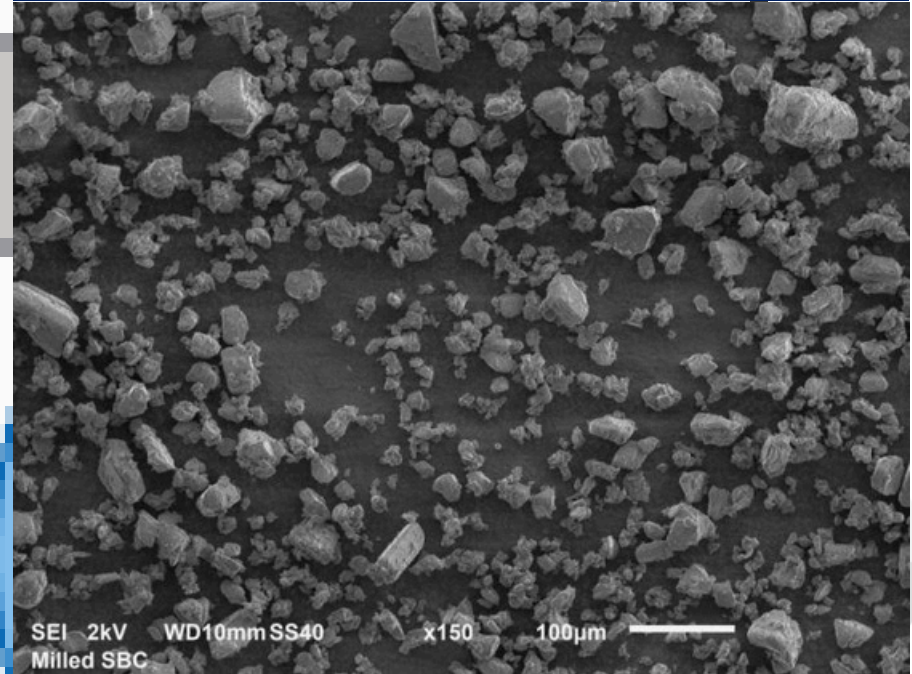


Unmilled SBC



180-350  m

Milled SBC



<30  m

Typical Large Scale DSI System



NRG Waukegan Station

- Unit 7 – 360 GMW
- Unit 8 – 385 GMW
- 100% low sulfur PRB coal
- CE Twin Furnace Boilers
- Trona or SBC injection at AHI
- 14 TPH Injection capacity per unit, plus 50% redundancy
- Achieve up to 90% SO₂ removal
- Actual injection rates less than guarantees and significantly less than system capacity

NTPC Dadri Power Plant DSI Project

- Four 210 MW Units with ESPs
- Approximately 62.5 percent SO₂ removal needed
- SBC injection at the air preheater inlet
- Each DSI system includes the following major components:
 - Truck and jumbo bag unloading system with blowers and dehumidifiers
 - 500 m³ storage silo
 - Two loss-in weight feed trains
 - Two conveying lines with blowers and dehumidifiers
 - Two UCC VIPER Mills
 - Two auto-purge splitters (one per duct)
 - 12 UCC COBRA II Lances (6 per duct)
- System commissioned in 2020

DSI System – Projects under execution by Isgec



Sr. No.	Client	Project Name	Plant Capacity (in MW)	Location	Baseline SO _x @ Guarantee Condition	Target SO _x @ Guarantee Condition	%SO ₂ Removal Efficiency
1	MAHAGENCO	Khaperkheda Units # 3&4	2x210	Maharashtra	1500 mg/Nm ³	500 mg/Nm ³	67%
2	WBPDCL	Kolaghat TPS Units# 3,4,5&6	4x210	West Bengal	1410 mg/Nm ³	575 mg/Nm ³	59.2%
3	MAHAGENCO	Khaperkheda Units# 1&2	2x210	Maharashtra	1500 mg/Nm ³	500 mg/Nm ³	67%

DeSO_x – Brief Technology Comparison and Suitability – Conclusion



Sr. No.	DESCRIPTION	WET FGD	SEMI DRY FGD	DRY SORBENT INJECTION SYSTEM
1.	REAGENT	LIMESTONE	HYDRATED LIME	SODIUM BICARBONATE
2.	BYPRODUCT	GYPSUM	Dry by-product can be used for landfill.	No Separate Byproduct mixes with Flyash
3.	SO₂ REMOVAL EFFICIENCY	Upto 99%	>95%	65-70%
4.	SO₃ REMOVAL EFFICIENCY	<40%	>95%	-
5.	SUITABLE FOR	>300 MW	<300 MW	210-250 MW with less remaining Life of the plant
6.	CAPEX	HIGHEST	MODERATE	LOWEST
7.	OPEX (w.r.t Reagent)	LOWEST	MODERATE	HIGHEST

Questions?



THANK YOU!

Presenter Information

Name: Amrit Kumar Halder
Phone: +91-8800557787
Email: amrithalder@isgec.co.in



**Thanking You
on Behalf of !**



Council of Enviro Excellence