KC Cottrell

Flue Gas Desulfurization

Wet Limestone-Gypsum Process

2016

A company that researches ways to safeguard the natural beauty of our planet.
A company whose mission is to keep our environment green to protect future dreams.
A company that co-exists with nature, recognizing that the environment is the most valuable asset.
KC Cottrell is preparing for the future with a firm commitment to the environment.

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Contents

Current Regulations – Thermal Power Plants

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Air Pollution –Current Regulations in India as per MoEF# Notification dated December 7, 2015

Pollutants (Unit: mg/Nm^3)	*TPPs installed before December 31, 2003	*TPPs installed after 2003 upto December 31, 2016	*TPPs to be installed from January 1, 2017
SO_2	200	200	100
PM	100	50	30
NO_X	600	300	100
Hg	0.03	0.03	0.03

- *The data mentioned above is for TPPs (Thermal Power Plants) > 500 MW. Only for SO_2 emissions for smaller th an 500 MW units, the standard is 600 mg/ Nm^3 , for units installed before 31st Dec 2003 and after 2003 upto Dec 31, 2016.
- #MoEF – Ministry of Environment, Forests & Climate Change (Control Pollution Control Board)
- TPPs (units) shall meet the limits within two years from date of publication of the notification

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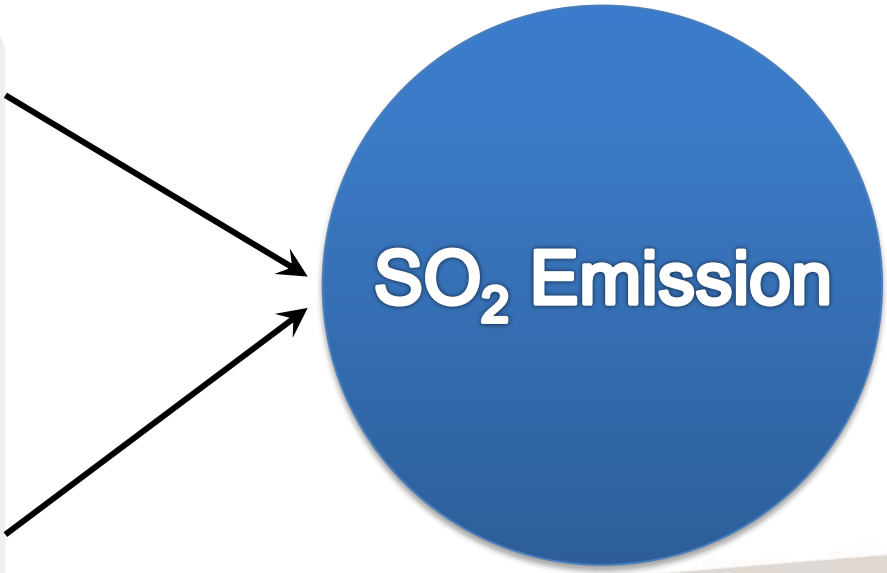
I. Introduction

Combustion of fossil fuels (e.g., coal and oil) → SOx

resulting in emissions of sulfur dioxide (SO_2) which can harm human health and deteriorate environments (Acid deposition & Soil acidification)

Total World Electricity Generation (2001)

- Coal 38.7%
- Gas 18.3%
- Nuclear 17.1%
- Hydro 16.6%
- Oil 7.5%
- Others 1.8%



Influence of Sulfur Oxides(SOx)

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Decrease of Visibility Range	Decrease visibility by absorbing or diffracting sun light in the atmosphere along with floated particles.
Bad Influence on HumanBody	Incidence of chronic diseases at eyes, nose, neck or bronchus by exposure for long time.
Bad Influence on Green Plants	Decrease production and growth of plants by interrupting photosynthesis due to the black spot or chlorosis.
Ecocide	Destruction of ecosystem by acidifying land or river due to acid rain or acid snow and corroding architectures.

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How to Control Sulfur Oxides(SOx)

Fuel Desulphurization Process

Method to remove SOx in the fuel prior to combustion

ex) Convert to low sulfur fuel by using catalyst with hydrogen in crude

Flue Gas Desulphurization Process

Method to remove SO_2 from emitted gas after combustion

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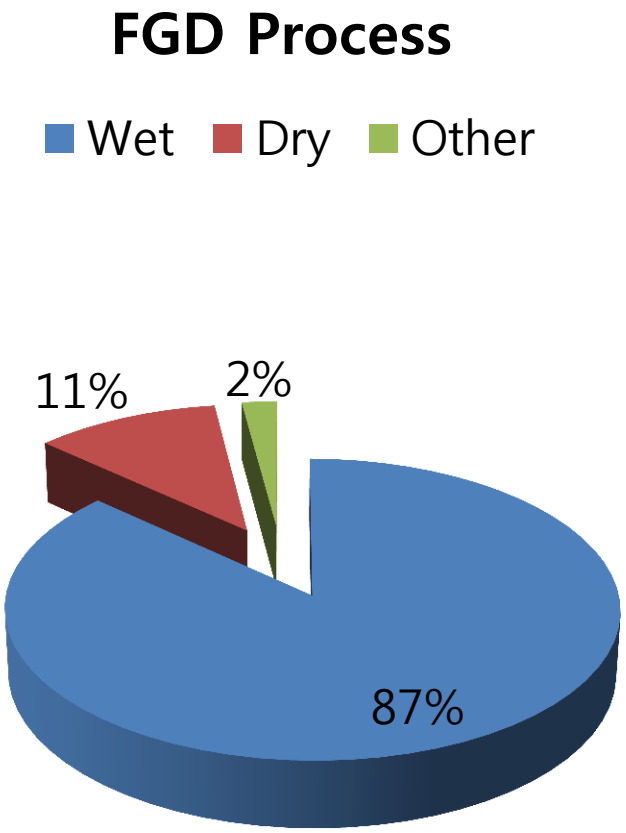
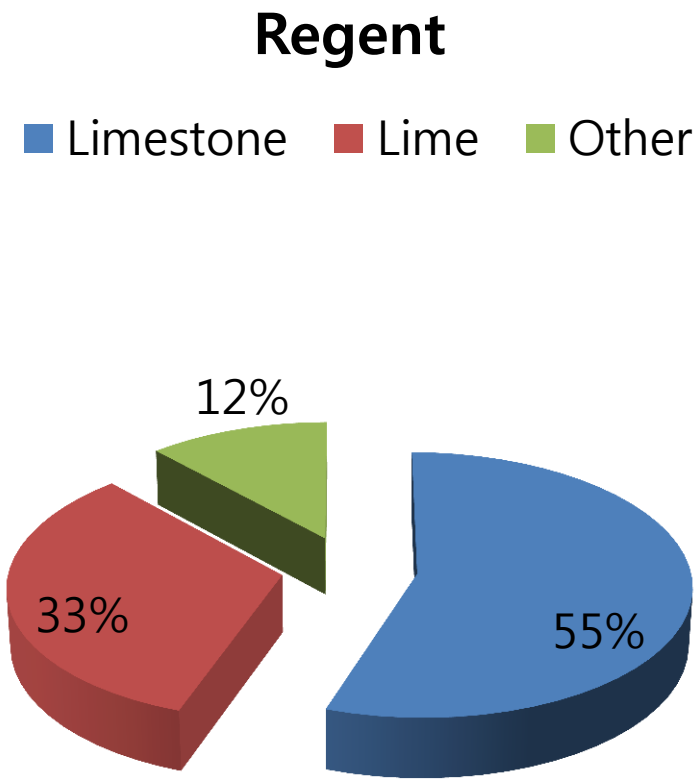
II. Type of FGD Process and Regent





Classification Based on Process

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	Wet	Semi-Dry	Dry
Characteristics	Slurry or solution → Reactor → Slurry or solution	Slurry or solution → Reactor → Dry powder	Dry powder → Reactor → Dry powder
Main reactor	Wet Scrubber	Semi Dry Reactor	Dry Injector
Application	Large / Medium Scale	Medium / Small Scale	Medium / Small Scale
Agents	Na, Mg, Ca compounds	Na, Mg, Ca compounds	Mg, Ca , Na compounds
Removal efficiency	≥ 90 %	≒ 90 %	40 – 90 %
Waste water treatment	necessary	unnecessary	unnecessary
Byproduct	Reuse	Landfill	Landfill
Investment cost / operation cost	High/Low	Medium/Medium	Low/High

Classification Based on Chemicals

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	Lime(stone) Scrubbing	Magnesium Scrubbing	Sodium Scrubbing	Ammonia Scrubbing
Kind of Chemical	$CaCO_3$, $Ca(OH)_2$	$Mg(OH)_2$ $MgCO_3$	NaOH, Na_2CO_3	NH_3, NH_4OH
Reactivity	Low	Medium	High	High
Overall Reaction Mechanism	$CaCO_3 + SO_2 + 2H_2O + \frac{1}{2}O_2 \rightarrow CaSO_4\ 2H_2O + CO_2$	$Mg(OH)_3 + SO_2 + 11H_2O + \frac{1}{2}O_2 \rightarrow MgSO_4\ 12H_2O$	$NaOH + SO_2 \rightarrow Na_2SO_3$	$2NH_3 + SO_2 + 2H_2O \rightarrow (NH_4)_2SO_4$
Phase of Product	$CaSO_4\ 2H_2O$ (Solid)	$MgSO_4\ 12H_2O$ (Slurry)	Na_2SO_3 (Solution)	$(NH_4)_2SO_4$ (Solid)
Scale Potential	High	Medium	Low	Medium
Application	Power Plant	Small Power Plant	Industrial Boiler	Power Plant
Removal Efficiency	> 90 %	> 90 %	> 95 %	> 95 %
Waste Water System	Small	Big	Big	Small
Capital Cost	High	Medium	Low	Higher than Lime
Operation Cost	Low	Medium	High	Medium

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III. Wet Limestone Gypsum Process

- The flue gas scrubbing process using limestone or lime as an absorbent and producing gypsum as a byproduct represents the proven process worldwide for flue gas desulfurization

- SO_2 Removal efficiency : ≥90%

- Availability : ≥99%

- Absorbent : Limestone
  - $CaCO_3$ 90%, grain size 200mesh D_{70}~325meshD_{95}
  - Stoichiometric ratio(S/R) : 1.03 ~ 1.05

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- By-product : Gypsum
  - Plaster board : free moisture ≤10%, purity ≥95%
  - Cement : free moisture ≤10%, purity ≥90%
  - Reclamation / Disposal etc.

- Sub-Process
  - Absorber & Auxiliary system
  - Flue gas system
  - Limestone slurry preparation system
  - Gypsum dewatering system
  - Waste water treatment system

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- **Material Balance**
  - **Particulate and SO_2 removal**
  - **Limestone requirement**
  - **Scrubber system material balance**
  - **Overall water balance**
  - **Steady-state soluble species levels in scrubber liquor & LAP**

- **Simplified Chemical Reaction in Absorber**
  - **Absorption : $SO_2 + H_2O \Rightarrow HSO_3^- + H^+$**
    $CaCO_3 + 2H^+ \Rightarrow Ca^{2+} + CO_2 + H_2O$
  - **Oxidation : $HSO_3^- + ½O_2 \Rightarrow SO_4^{2-} + H^+$**
    $Ca^{2+} + SO_4^{2-} + 2H_2O \Rightarrow CaSO_4 2H_2O$

Process Chart of FGD

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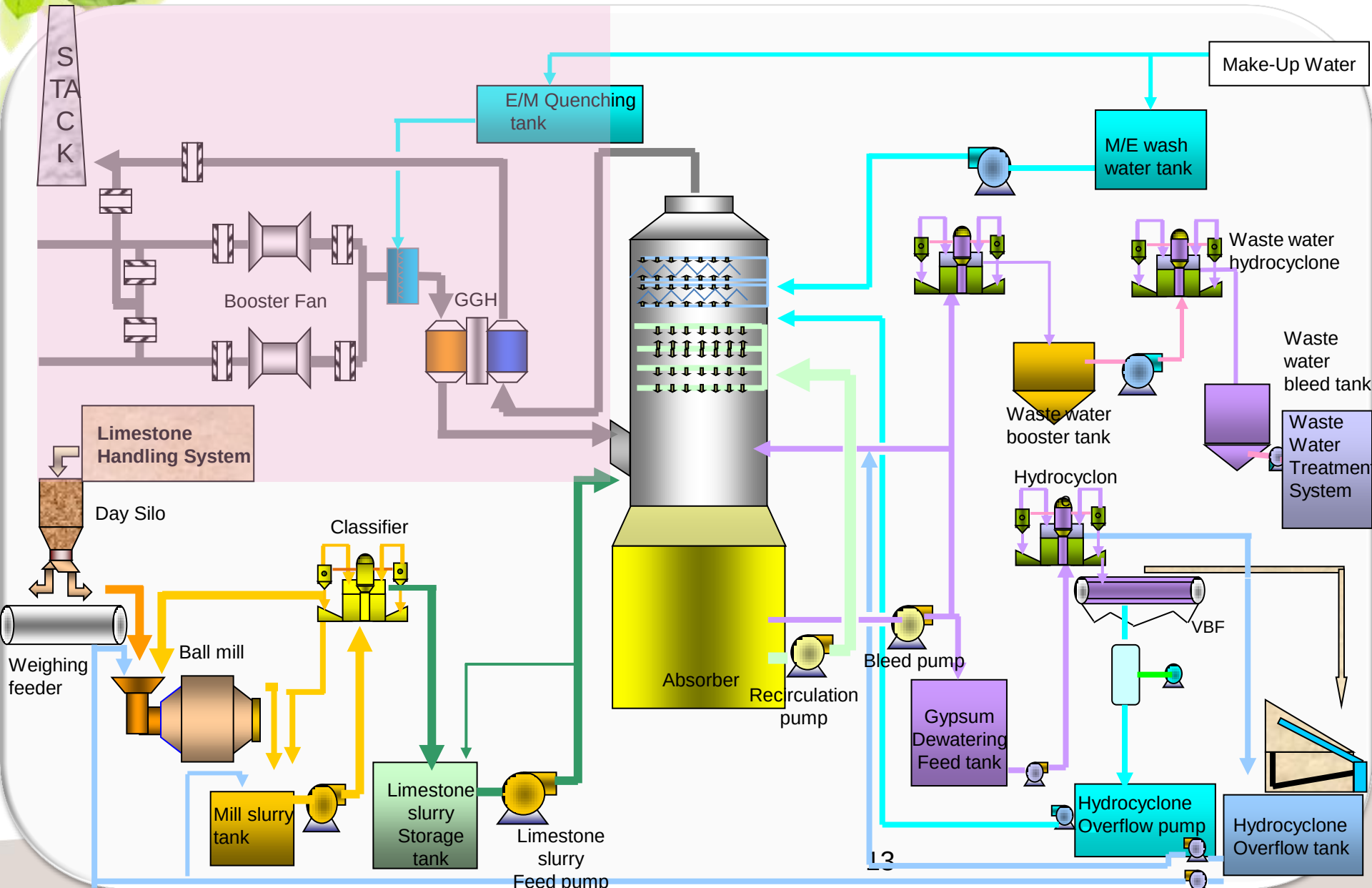

Overall System Mass Balance

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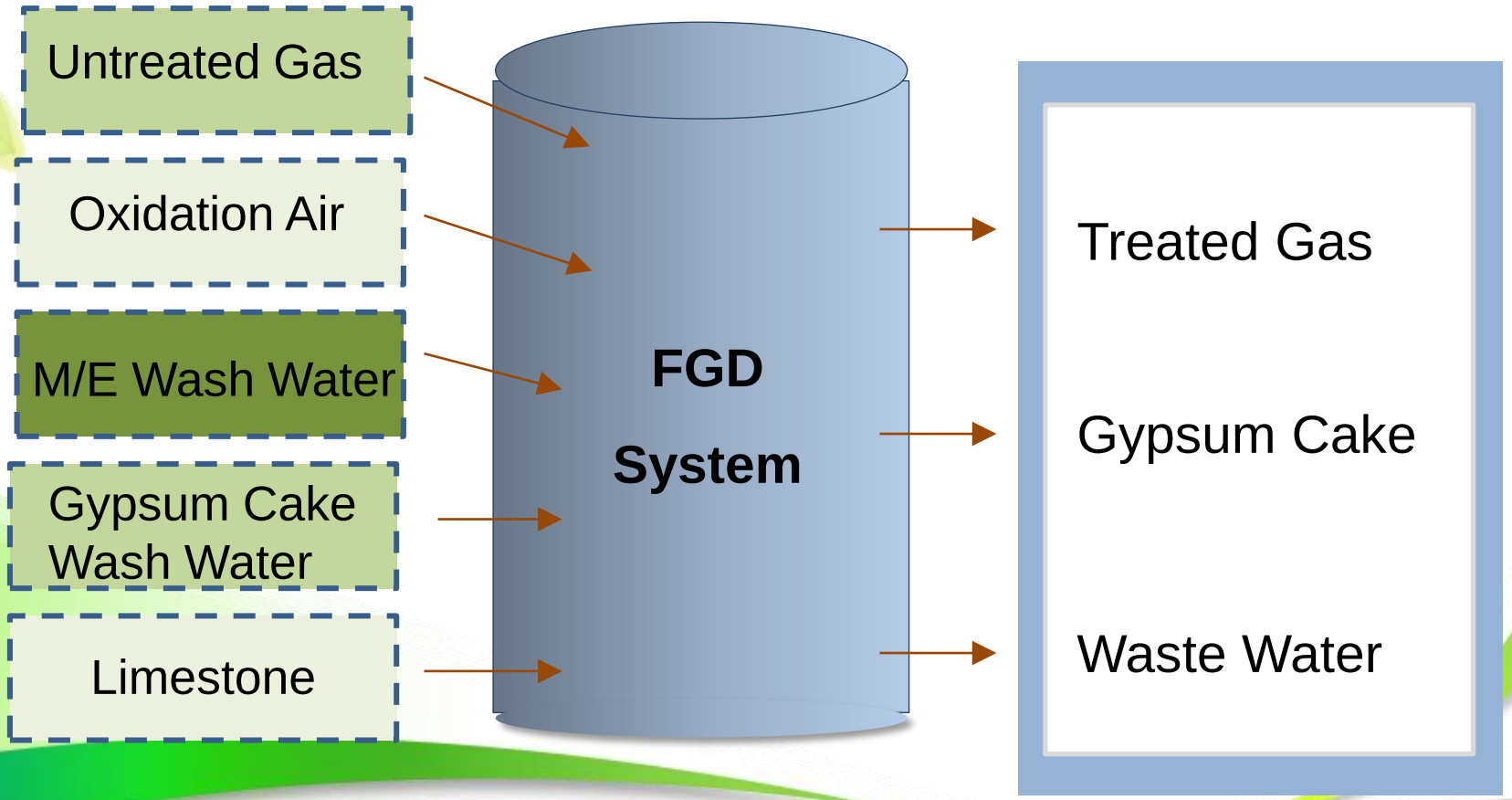

Process Chemistry for Wet Limestone FGD

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- SO_2 Absorption (H_2SO_3)
- Limestone Dissolution ($CaCO_3$)
- Creation of Calcium Sulfite ($CaSO_3$)
- Oxidation of Calcium Sulfite ($CaSO_4.2H_2O$)
- Separation Gypsum from Absorber Slurry

$$SO_2(g) + H_2O \Leftrightarrow H_2SO_3(aq) \Leftrightarrow HSO_3^- + H^+$$

$$CaCO_3(s) \Leftrightarrow CaCO_3(aq) + H^+ \Leftrightarrow Ca^{+2} + HCO_3^-$$

$$HCO_3^- + HSO_3^- \Leftrightarrow SO_3^{-2} + H_2O + CO_2$$

$$SO_3^{-2} + Ca^{+2} \Leftrightarrow CaSO_3$$

$$HSO_3^- + 1/2O_2 \Leftrightarrow SO_4^{-2} + H^+$$

$$Ca^{+2} + SO_4^{-2} + 2H_2O \Leftrightarrow CaSO_4 2H_2O$$

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- **Absorber type : Open Spray, Venturi, Tray, Packed, Jet Bubbling**

- **Open spray tower**
  - **Simply internal structure**
  - **Superficial gas velocity : 3 ~ 4m/s**
  - **Liquid / Gas ratio : 10~20ℓ/㎥**
  - **pH in reaction tank : 4~6 (LS Slurry feed)**
  - **Solid Content : 15~20% (GS Slurry bleed)**
  - **Slurry Residence Time : 4~6 sec**
  - **Solid residence time : ≥15hr**
  - **Chloride content in reaction tank : ~ 30000ppm(WW bleed)**
  - **Wet-dry zone, Spray zone, ME zone, Reaction tank (LS dissolution, Oxidation, GS crystallization)**
  - **Material : Rubber lining, Flake glass lining, Duplex Stainless Steel, Ni-alloy(Clad or Solid)**

Absorber Internals (Open Spray Tower)

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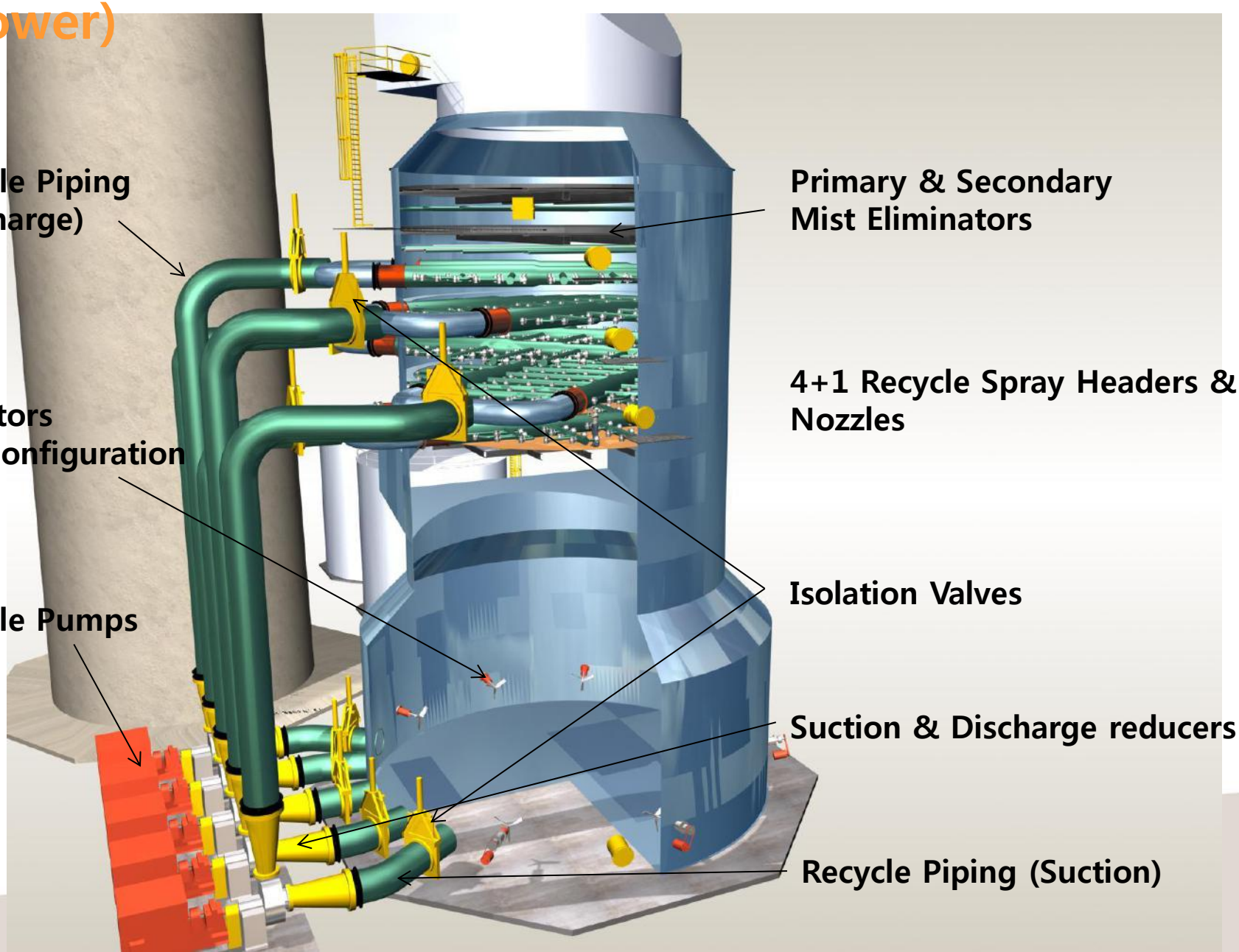

Spray(Absorption) Zone

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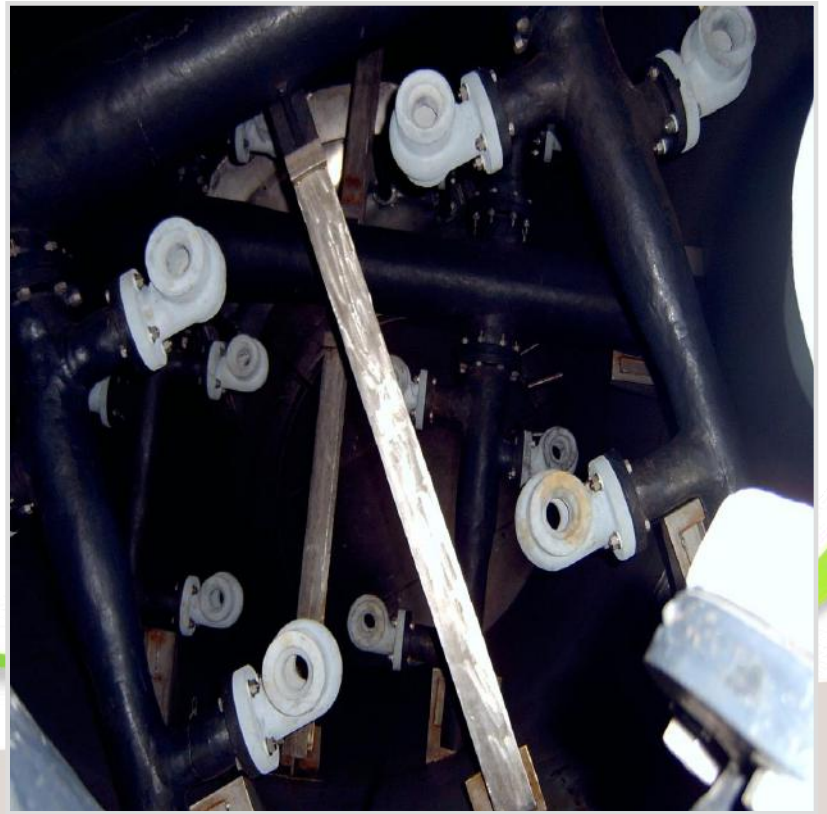
- The area where Limestone ($CaCO_3$) suspension is injected through Spray Header and Nozzle, SO_2 of combustion gas is absorbed.
- Absorption efficiency depends on the amount of scrubbing liquid, the size of particle, velocity of gas and contact duration or ratio between gas/liquid.



Reaction Zone

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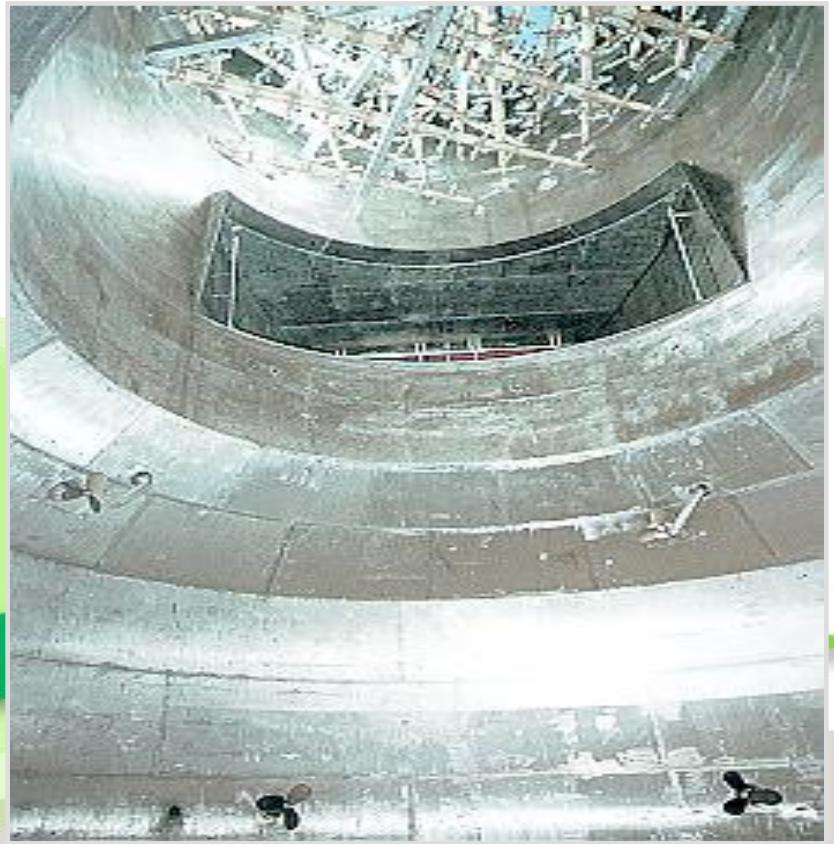
The area where the absorbent ($CaCO_3$) taken SO_2 change to gypsum through complete oxidation.

To help oxidation reaction, air blower with lance pipe is installed and to prevent plugging or deposition, agitator is installed in inside of reactor.



Clean Zone

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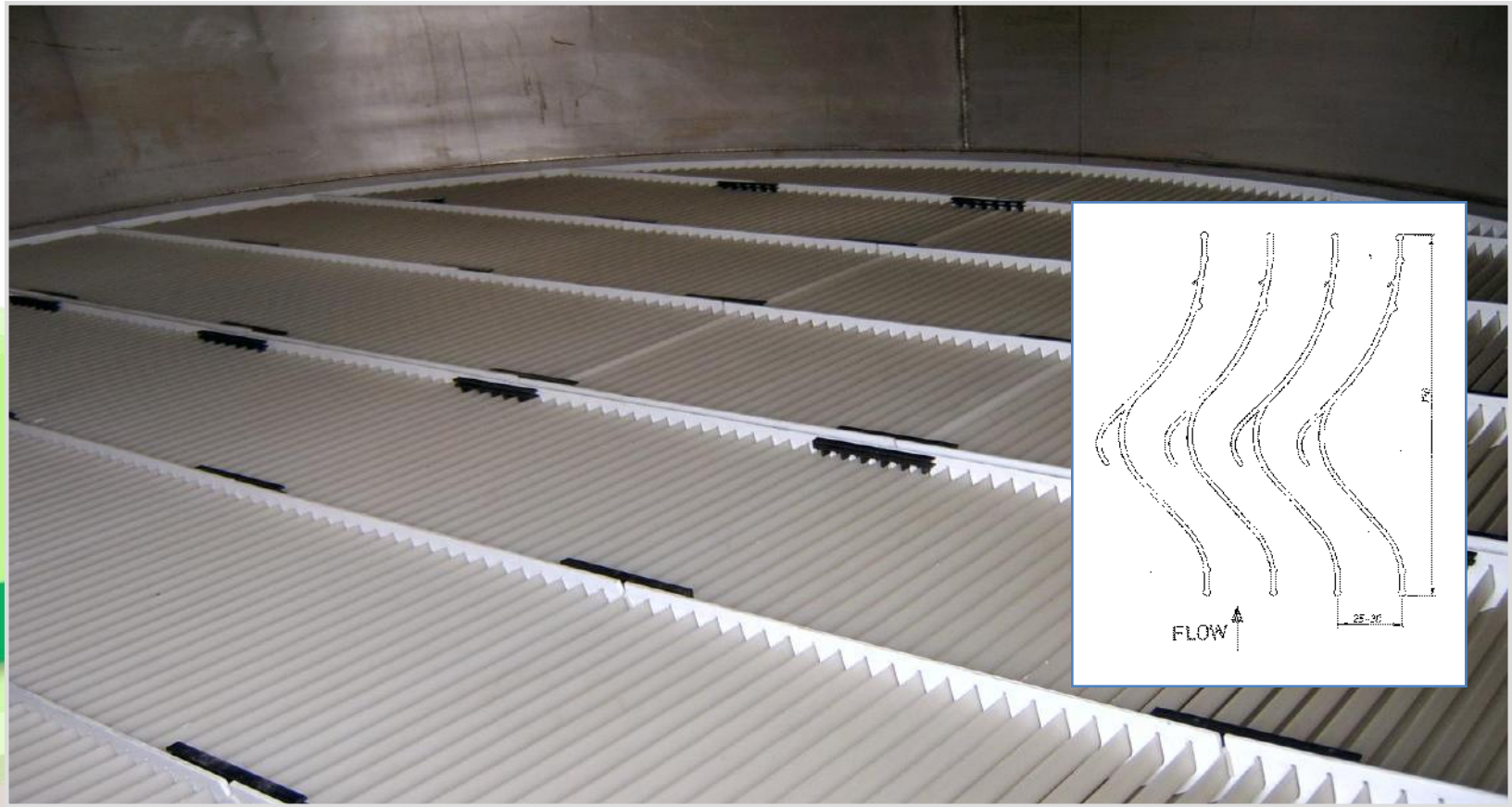
Clean gas came out from Spray Zone after absorption is completed contains water droplets which result into plugging, corrosion & scale as this droplet contains supersaturated gypsum and alkaline matter. By installing mist eliminator in this area, those phenomenon will be prevented.



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Trend of WFGD Technology

1. High SO2 Removal Efficiency : > 95%
   - High sulfur coal and stricter regulation
   - Upgrading exist FGD
   - Organic acid additive(DBA)
2. High Speed Absorber
   - Decrease Abs size & Increase L/G reaction time
3. Improvement of L/G Ratio
   - Dual flow spray nozzle
   - Ring wall(LDR), Even gas distribution
4. Reducing GGH Leakage

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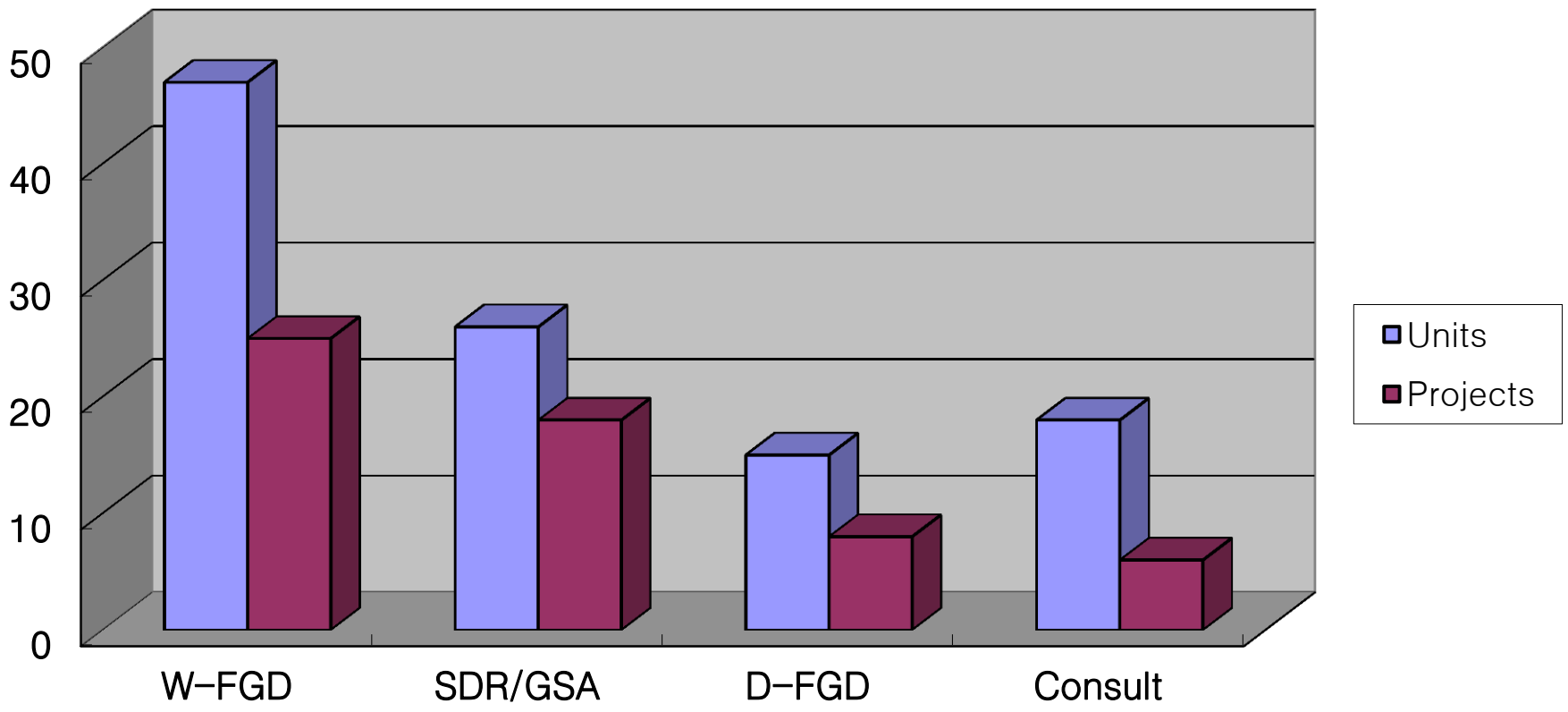
IV. KC's FGD References

No of FGD References



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FGD by KC COTTRELL

1. Various Scales : Small to Large(10,000~4,700,000 m^3/hr)
2. Various Process : Wet, Semi-dry, Dry
3. Various Reagent : CaCO3, $Ca(OH)_2$, NaOH, $NaHCO_3$, $Mg(OH)_2$, Waste Alkali Water, etc
4. Various Application : Power(Coal/Oil/Orimulsion), Steel, Cement, Incinerator, Industrial Boiler, etc.
5. Well Proven Technology & Optimized System Design
6. Capability of Turn-key base Project Execution
7. Utilizing the KC's Global Network and Resources
8. Providing Total Solution on Environmental Issues : Air Pollution, Landfill, Recycle, Incineration, etc

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Limestone-Gypsum Wet FGD by KC Cottrell

1. Open Spray Tower
2. Lower Pressure Drop through Absorber
   (=Lower Power Consumption)
3. Less Gypsum Scale Potential
   and Less Maintenance in Absorber
4. Higher Operation Availability & Reliability (>99%)
5. Higher Availability of Reagent i.e, Lower S/R
6. Optimized System Design with High SO_2 Removal
   Efficiency

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Absorber Test Tower

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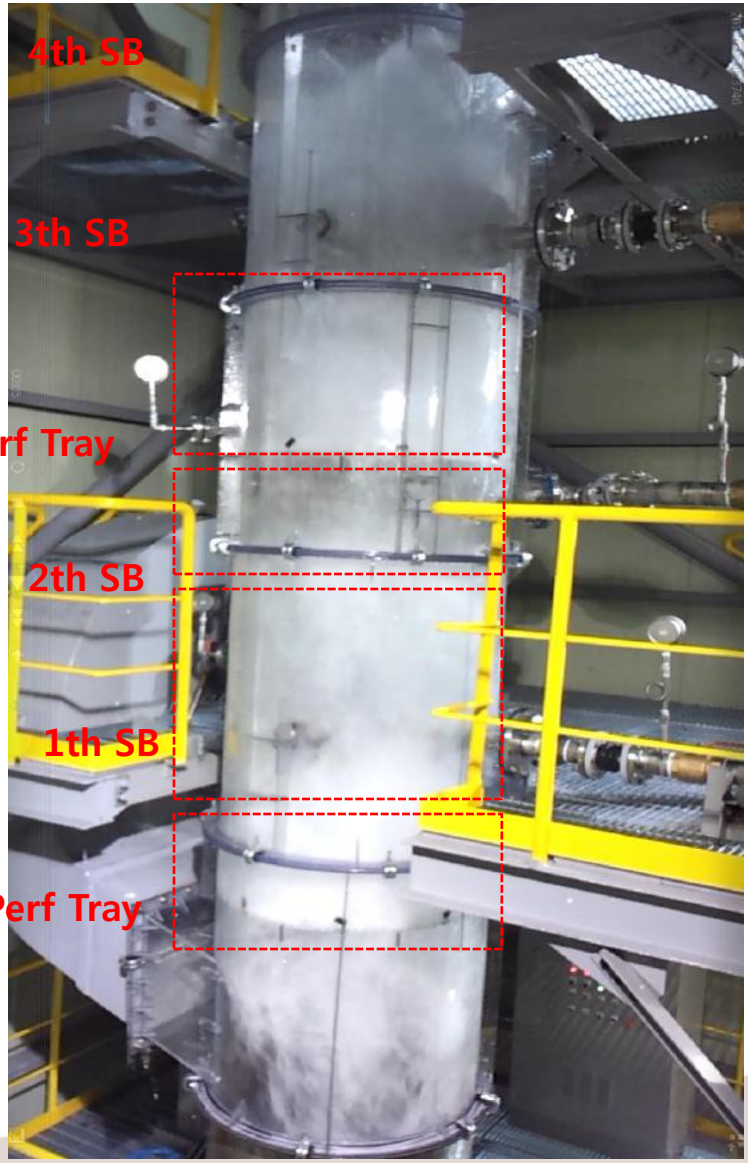

Tangjin T/P (4 x 500MW)

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FGD Absorber

- Wet Limestone-Gypsum Process
- SO_2 Removal efficiency: >95%
- FGD commercial operation: since 1997
- Scope: Turn-key FGD project including
  - -Limestone slurry preparation
  - -Gypsum dewatering plant
  - -FGD waste water treatment
- Contract Amount : 160 Mil.USD

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Ball Mill

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Vacuum Belt Filter

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Waste Water Treatment

Cheongju FGD for CHP & HOB

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- Wet Limestone-gypsum Process
- CHP Boiler: 260t/hr – 61,400KW x 1unit
- HOB Boiler: 150t/hr x 2units
- 90% SO2 removal efficiency
- 1%S B–C Oil (Design base)
- Powdered limestone slurry preparation
- Gypsum dewatering plant with centrifuge
- Material: 25-6Mo, Duplex S.S,
  Flake glass lining, FRP, etc

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Limestone Silo

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Centrifuge

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Gypsum Shed

Youngnam T/P Units 1&2

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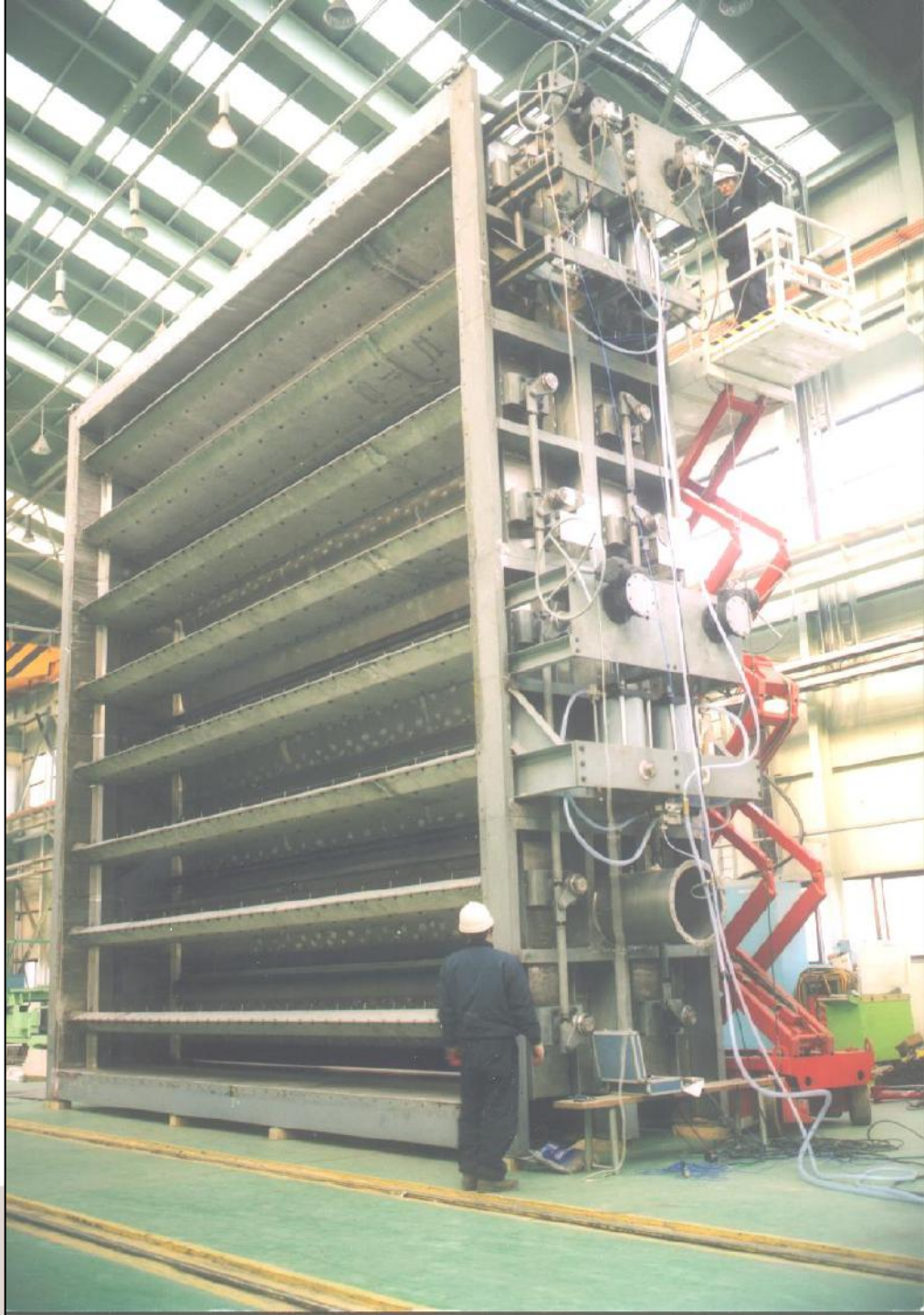
- Unit Electic Capacity : 125MW & 200MW
- Retrofit for Orimulsion fuel conversion for B-C & Orimulsion Combined Use
- Retrofit of Wet Limestone-Gypsum FGD System for High Sulfur Orimulsion fuel (≈3%)
- High SOx Removal Efficiency (≥99%) with DBA additive injection system
- Blue Fume Removal System using Magnesium Injection at Boiler, A/H & GGH
- Waste water treatment system of Evaporizing Concentration Type
- Upstream SCR Arrangement and Honeycomb Type Catalyst using Anhydrous Ammonia Injection
- High corona induced discharge electrode of ESP with High current density
- High Density granulating System for ASH Handling

Hsinta T/P
Unit 3&4,Taiwan

- Wet Limestone Gypsum FGD
  for 500MW x 2 Units Coal Fired Boiler
- Providing Detail Engineering for
  Flue gas system, Steel structure & etc.
- High reliability Damper Supply
  - Guillotine, Single & Double Louver
  - Max. size : 7,600W x 7,600H
- Client : IHI, User : TPC



Daegu Dyeing Industrial Center

- Coal Fired Boiler (150Ton/hr)
- Packed Tower Scrubbing System with 90% SO_2 Removal Efficiency
- Waste Alkali Water used as Absorbent

Bridgestone Carbon Black Plant, Thailand

- Wet Limestone Gypsum Process
- Co-generation Boiler & Carbon Black Plant (211,500 A㎥/hr)
- Providing Basic Engineering and Major Equipments
- Using Powered Limestone and Centrifuge for Dewatering
- High SO2 Removal Efficiency (≥95%)
- Commercial grade of gypsum quality (≥92%)
- Self-sustained Wet Stack Discharge without GGH
- Client : Fujikasui Engineering Co

Tokai Carbon Product, Thailand

- Wet Limestone – Gypsum Process using Powered Limestone and Centrifuge for Dewatering
- Co-generation Boiler & Carbon Black Plant (158,800 A㎥/hr)
- Providing Basic Engineering and Major Equipments
- High SO_2 Removal Efficiency (≥90%)
- Commercial grade of gypsum quality (≥92%)
- Flue Gas By-Pass Reheating without GGH
- Client : Fujikasui Engineering Co

Jeju T/P (1 x 40MW)

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Samchonpo T/P (4 x 560MW)

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- Coal Firing / Wet Limestone-Gypsum Process
- 91% SO2 Removal efficiency at 1.05%S Coal(Design base)
- Turnkey FGD Project including
  Limestone & Gypsum Handling System,
  FGD Waste water treatment,
  Limestone slurry preparation with Wet Ball Mill
  Gypsum dewatering plant with H/C & VBF
- Stack Inner flue basic design & modification
- Material : C276, 4.5%Mo etc.

Hadong T/P #7&8 (2 x 500MW)

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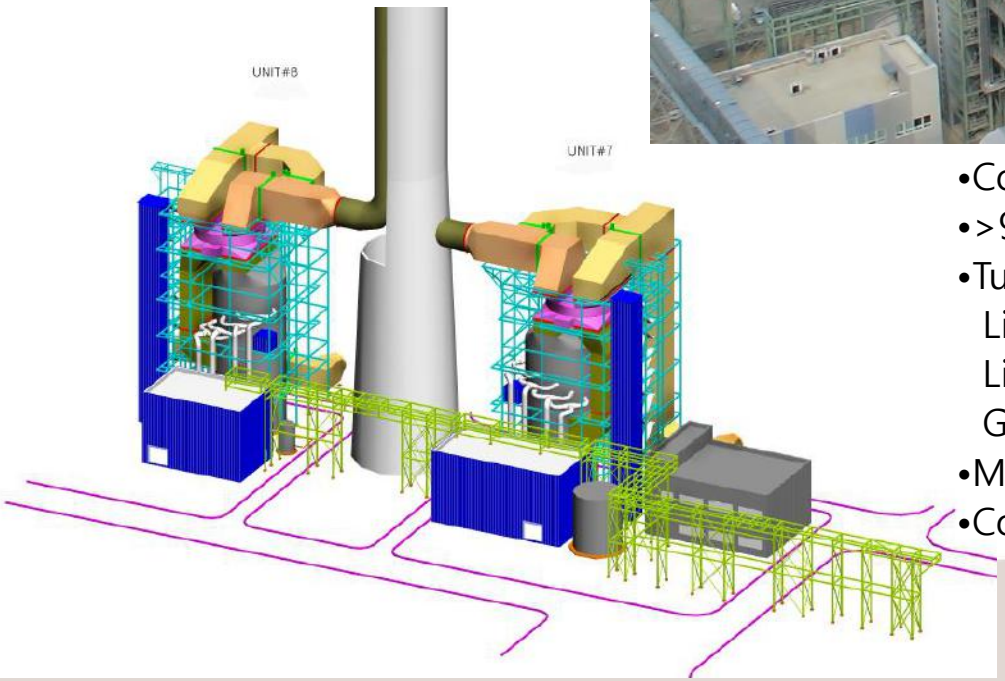

- Coal Firing / Wet Limestone-Gypsum Process
- >93.5% Guaranteed SO2 Removal efficiency
- Turnkey FGD Project including
  - Limestone & Gypsum Handling System
  - Limestone slurry preparation with Wet Ball Mill
  - Gypsum dewatering plant with H/C & VBF
- Material of Absorber : C276, 256Mo, etc
- Commercial Operation Schedule

  Unit #7 : Dec. 30, 2008, Unit #8 : Jun. 31, 2009

Hsinta T/P (2 x 500MW)

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- Wet Limestone-Gypsum Process
- Upgrading of Exist FGD Supplied by GE (Including ESP & AHS)

Absorber Slurry Recycle Header Demolition

Prescrubber / Cooler Demolition

Gwangyang #1-4 Sinter Plnat

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- User / Client : POSCO
- Dry FGD System, SBC($NaHCO_3$)/RSC(Na_2CO_3) Injection with Bag Filter and Ash Extractor
- Gas Flow : 1,350,000 Nm^3/hr (wet) x 4 Units
- >90% SO_2 Removal efficiency (Guarantee > 80%)
- Turnkey Project including De-Dioxin & SCR, Duct Burner, GGH, etc
- Construction Period : 2005.5.12~2007.6.30 (26 months)

Visible Fume – Stack with FGD and without FGD

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POSCO GWANGYANG #1-4 SINTER PLANT

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THANK YOU!
QUESTIONS?

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