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.
Contents

Ⅰ. Introduction
Ⅱ. Type of FGD Process & Regent
Ⅲ. Wet Limestone Gypsum Process
Ⅳ. KC’s FGD References
Current Regulations – Thermal Power Plants

<table>
<thead>
<tr>
<th>Pollutants (Unit: mg/Nm³)</th>
<th>*TPPs installed before December 31, 2003</th>
<th>*TPPs installed after 2003 upto December 31, 2016</th>
<th>*TPPs to be installed from January 1, 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>200</td>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td>PM</td>
<td>100</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>NOₓ</td>
<td>600</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td>Hg</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
</tr>
</tbody>
</table>

*The data mentioned above is for TPPs (Thermal Power Plants) > 500 MW. Only for SO₂ emissions for smaller than 500 MW units, the standard is 600 mg/ Nm³, 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.
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)

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease of Visibility Range</td>
<td>Decrease visibility by absorbing or diffracting sun light in the atmosphere along with floated particles.</td>
</tr>
<tr>
<td>Bad Influence on Human Body</td>
<td>Incidence of chronic diseases at eyes, nose, neck or bronchus by exposure for long time.</td>
</tr>
<tr>
<td>Bad Influence on Green Plants</td>
<td>Decrease production and growth of plants by interrupting photosynthesis due to the black spot or chlorosis.</td>
</tr>
<tr>
<td>Ecocide</td>
<td>Destruction of ecosystem by acidifying land or river due to acid rain or acid snow and corroding architectures.</td>
</tr>
</tbody>
</table>
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 SO₂ from emitted gas after combustion
II. Type of FGD Process and Regent

FGD Process
- Wet: 87%
- Dry: 11%
- Other: 2%

Regent
- Limestone: 55%
- Lime: 33%
- Other: 12%
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Wet</th>
<th>Semi-Dry</th>
<th>Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics</td>
<td>Slurry or solution → Reactor → Slurry or solution</td>
<td>Slurry or solution → Reactor → Dry powder</td>
<td>Dry powder → Reactor → Dry powder</td>
</tr>
<tr>
<td>Main reactor</td>
<td>Wet Scrubber</td>
<td>Semi Dry Reactor</td>
<td>Dry Injector</td>
</tr>
<tr>
<td>Application</td>
<td>Large / Medium Scale</td>
<td>Medium / Small Scale</td>
<td>Medium / Small Scale</td>
</tr>
<tr>
<td>Agents</td>
<td>Na, Mg, Ca compounds</td>
<td>Na, Mg, Ca compounds</td>
<td>Mg, Ca, Na compounds</td>
</tr>
<tr>
<td>Removal efficiency</td>
<td>≥ 90 %</td>
<td>≃ 90 %</td>
<td>40 – 90 %</td>
</tr>
<tr>
<td>Waste water treatment</td>
<td>necessary</td>
<td>unnecessary</td>
<td>unnecessary</td>
</tr>
<tr>
<td>Byproduct</td>
<td>Reuse</td>
<td>Landfill</td>
<td>Landfill</td>
</tr>
<tr>
<td>Investment cost / operation cost</td>
<td>High/Low</td>
<td>Medium/Medium</td>
<td>Low/High</td>
</tr>
</tbody>
</table>
## Classification Based on Chemicals

<table>
<thead>
<tr>
<th>Kind of Chemical</th>
<th>Lime(Stone) Scrubbing</th>
<th>Magnesium Scrubbing</th>
<th>Sodium Scrubbing</th>
<th>Ammonia Scrubbing</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaCO₃, Ca(OH)₂</td>
<td>Mg(OH)₂ MgCO₃</td>
<td>NaOH, Na₂CO₃</td>
<td>NH₃, NH₄OH</td>
<td></td>
</tr>
<tr>
<td>Reactivity</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Overall Reaction Mechanism</td>
<td>CaCO₃ + SO₂ + 2H₂O + 1/2 O₂ → CaSO₄ 2H₂O + CO₂</td>
<td>Mg(OH)₃ + SO₂ + 11H₂O + 1/2 O₂ → MgSO₄ 12H₂O</td>
<td>NaOH + SO₂ → Na₂SO₃</td>
<td>2NH₃ + SO₂ + 2H₂O → (NH₄)₂SO₄</td>
</tr>
<tr>
<td>Phase of Product</td>
<td>CaSO₄ 2H₂O (Solid)</td>
<td>MgSO₄ 12H₂O (Slurry)</td>
<td>Na₂SO₃ (Solution)</td>
<td>(NH₄)₂SO₄ (Solid)</td>
</tr>
<tr>
<td>Scale Potential</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Application</td>
<td>Power Plant</td>
<td>Small Power Plant</td>
<td>Industrial Boiler</td>
<td>Power Plant</td>
</tr>
<tr>
<td>Removal Efficiency</td>
<td>&gt; 90 %</td>
<td>&gt; 90 %</td>
<td>&gt; 95 %</td>
<td>&gt; 95 %</td>
</tr>
<tr>
<td>Waste Water System</td>
<td>Small</td>
<td>Big</td>
<td>Big</td>
<td>Small</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Higher than Lime</td>
</tr>
<tr>
<td>Operation Cost</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
</tr>
</tbody>
</table>
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.

- $\text{SO}_2$ Removal efficiency : $\geq 90\%$

- Availability : $\geq 99\%$

- Absorbent : Limestone
  - $\text{CaCO}_3$ 90%, grain size 200mesh $D_{70} \sim 325\text{mesh}D_{95}$
  - Stoichiometric ratio($S/R$) : 1.03 ~ 1.05
• **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
• **Material Balance**
  - Particulate and SO₂ 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: \( \text{SO}_2 + \text{H}_2\text{O} \Rightarrow \text{HSO}_3^- + \text{H}^+ \)
    \[ \text{CaCO}_3 + 2\text{H}^+ \Rightarrow \text{Ca}^{2+} + \text{CO}_2 + \text{H}_2\text{O} \]
  - Oxidation: \( \text{HSO}_3^- + \frac{1}{2}\text{O}_2 \Rightarrow \text{SO}_4^{2-} + \text{H}^+ \)
    \[ \text{Ca}^{2+} + \text{SO}_4^{2-} + 2\text{H}_2\text{O} \Rightarrow \text{CaSO}_42\text{H}_2\text{O} \]
Process Chart of FGD

1. **Make-Up Water**
   - M/E wash water tank
   - Waste water booster tank
   - Waste water bleed tank

2. **Waste Water Treatment System**
   - Waste water hydrocyclone
   - Waste Water Treatment System

3. **Limestone Handling System**
   - Day Silo
   - Weighing feeder
   - Ball mill
   - Mill slurry tank
   - Limestone slurry storage tank
   - Limestone slurry feed pump

4. **Booster Fan**
   - GGH
   - E/M Quenching tank

5. **Absorber**
   - Recirculation pump
   - Gypsum dewatering feed tank
   - Hydrocyclone overflow pump
   - Hydrocyclone overflow tank

6. **Classifier**
   - Classifier

7. **Gypsum Dewatering Feed Tank**
   - Bleed pump

8. **Limestone Slurry Storage Tank**

9. **Waste Water Hydrocyclone**

10. **Waste Water Booster Tank**

11. **Waste Water Bleed Tank**

12. **Waste Water Treatment System**
Overall System Mass Balance

- Untreated Gas
- Oxidation Air
- M/E Wash Water
- Gypsum Cake
- Wash Water
- Limestone
- FGD System
- Treated Gas
- Gypsum Cake
- Waste Water
Process Chemistry for Wet Limestone FGD

SO₂ Absorption (H₂SO₃)

Limestone Dissolution (CaCO₃)

Creation of Calcium Sulfite (CaSO₃)

Oxidation of Calcium Sulfite (CaSO₄·2H₂O)

Separation Gypsum from Absorber Slurry

SO₂(g) + H₂O ↔ H₂SO₃(aq) ↔ HSO₃⁻ + H⁺

CaCO₃(s) ↔ CaCO₃(aq) + H⁺ ↔ Ca²⁺ + HCO₃⁻

HCO₃⁻ + HSO₃⁻ ↔ SO₃⁻² + H₂O + CO₂

SO₃⁻² + Ca²⁺ ↔ CaSO₃

HSO₃⁻ + 1/2O₂ ↔ SO₄⁻² + H⁺

Ca²⁺ + SO₄⁻² + 2H₂O ↔ CaSO₄·2H₂O
• Absorber type: Open Spray, Venturi, Tray, Packed, Jet Bubbling

• Open spray tower
  – Simply internal structure
  – Superficial gas velocity: 3 ~ 4 m/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)

- Recycle Piping (Discharge)
- Agitators 6+1 configuration
- 4 + 1 Recycle Pumps
- Primary & Secondary Mist Eliminators
- 4+1 Recycle Spray Headers & Nozzles
- Isolation Valves
- Suction & Discharge reducers
- Recycle Piping (Suction)
Spray(Absorption) Zone

• 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

The area where the absorbent (CaCO₃) taken SO₂ 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 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.
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
IV. KC’s FGD References

No of FGD References

- **W-FGD**: 50
- **SDR/GSA**: 26
- **D-FGD**: 7
- **Consult**: 8

**Legend**:
- Units
- Projects
**FGD by KC COTTRELL**

1. Various Scales: Small to Large (10,000~4,700,000 m³/hr)
2. Various Process: Wet, Semi-dry, Dry
3. Various Reagent: CaCO₃, Ca(OH)₂, NaOH, NaHCO₃, 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.
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
Absorber Test Tower
Tangjin T/P (4 x 500MW)

- 500MW Coal Firing
- Fuel: Bituminous coal
- Units 1-4: FGD/SCR
- Units 5&6: AHS
• Wet Limestone-Gypsum Process
• SO2 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
Waste Water Treatment
Cheongju FGD for CHP & HOB

- Wet Limestone-gypsum Process
- CHP Boiler: 260t/hr – 61,400KW x 1 unit
- HOB Boiler: 150t/hr x 2 units
- 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
Limestone Silo
Centrifuge
• Unit Electric 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
- 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
• Coal Fired Boiler (150Ton/hr)
• Packed Tower Scrubbing System with 90% SO₂ 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 Am³/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 Am³/hr)
- Providing Basic Engineering and Major Equipments
- High SO₂ 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)

- NaOH Scrubbing Process
- Diesel Power Station
- Provided FGD & ESP
Samchonpo T/P (4 x 560MW)

• 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)

- 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)

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

Absorber Slurry Recycle
Header Demolition

Prescrubber / Cooler
Demolition
User / Client : POSCO

- Dry FGD System, SBC(NaHCO₃)/RSC(Na₂CO₃) Injection with Bag Filter and Ash Extractor
- Gas Flow : 1,350,000 Nm³/hr (wet) x 4 Units
- >90% SO₂ 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
THANK YOU!
QUESTIONS?