

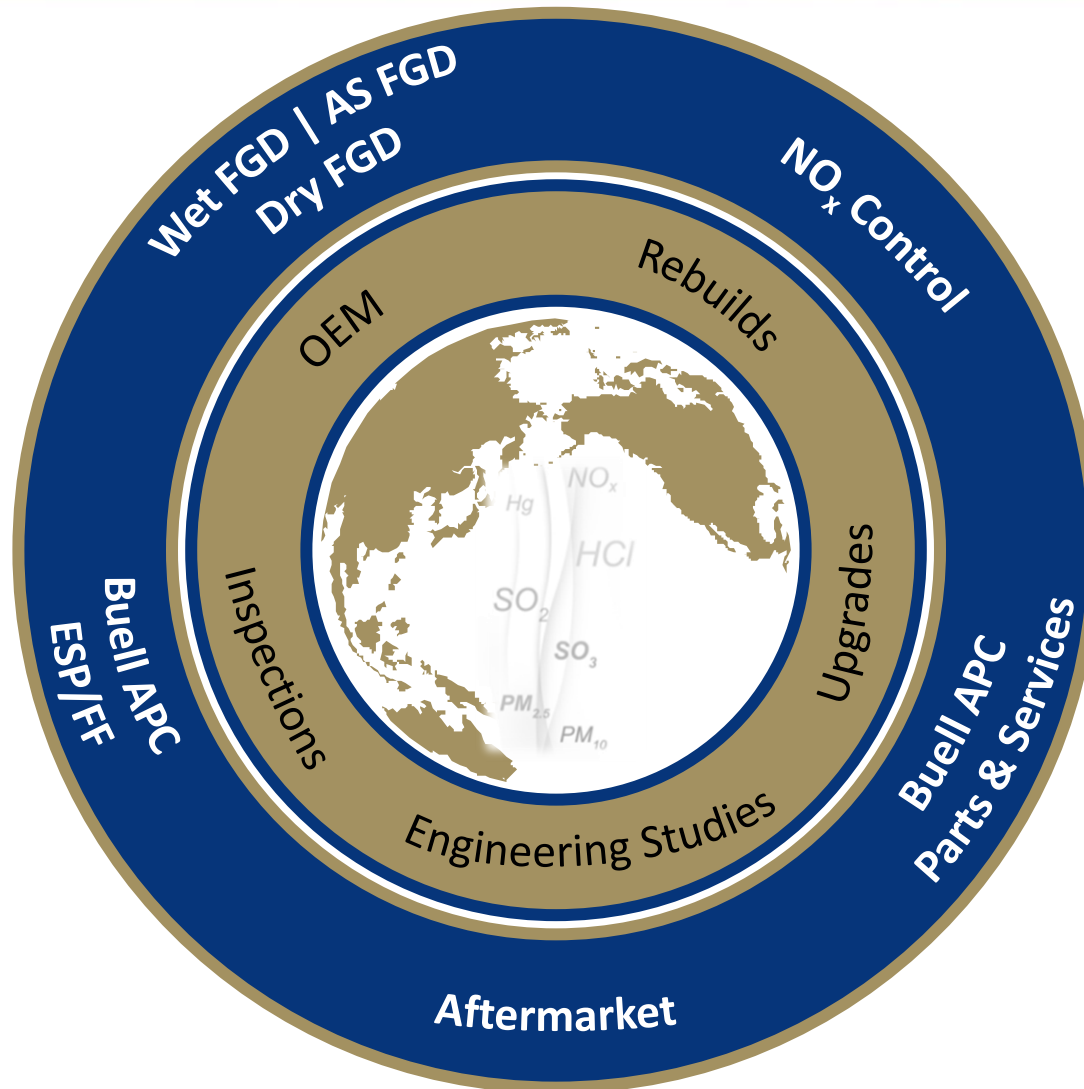


# Flue Gas Desulfurization - Process Overview

Presented by: Mike Hammer  
Senior Process Engineer  
Marsulex Environmental Technologies



# MET - Your Full Service AQC Solutions Provider



## Brief History

- **1934**: Buell Engineering Company Mechanical Collectors
- **1950 -1960s**: Buell ESP & fabric filter product lines added
- **1971**: Envirotech acquired Buell
- **1981**: Envirotech's Buell + Chemico FGD Divisions acquired by General Electric and incorporated as General Electric Environmental Services Inc (GEESI)
- **1997**: GEESI acquired by Marsulex
- **2019**: Kraft Powercon purchases MET, Thermax awarded first MET Licensed WFGD Contract in India



# Overview of Business – Summary of Services

## Installed Base

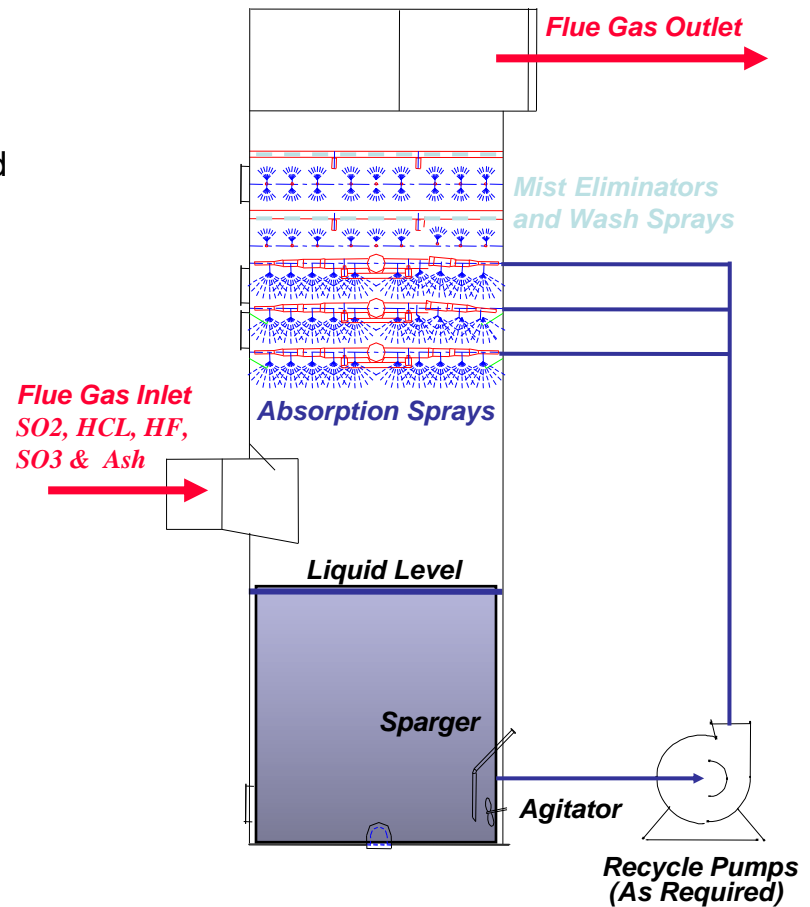
Traditional Flue Gas Desulphurization	Ammonium Sulfate FGD Technology	FGD Upgrades & Associated Services	Particulate Control	Selective Catalytic Reduction
<b>105,210 MW</b>	<b>2,250 MW</b>	<b>4,195 MW*</b>	<b>75,000+ MW</b>	<b>26,000 MW (4,000 USA)</b>
<ul style="list-style-type: none"> <li>Wet and Dry FGD solutions</li> <li>Utilizing reagents such as lime, limestone, and sodium</li> <li>Worldwide installations</li> </ul> <p><b>International FGD Licensing</b></p> <ul style="list-style-type: none"> <li>MET licenses the right to use MET technology in multiple international markets</li> </ul>	<ul style="list-style-type: none"> <li>Proprietary and patented SO<sub>2</sub> technology using ammonia as the reagent</li> <li>Valuable crop fertilizer by product provides pay back to owner</li> <li>Commercially demonstrated for over seventeen years.</li> <li>Operating Units in U.S.A., Canada, China and Poland</li> </ul>	<ul style="list-style-type: none"> <li>Performance upgrades on existing Wet and Dry FGD</li> <li>Aftermarket services for Wet and Dry FGD systems</li> <li>Engineering studies</li> <li>Field advisory services and training</li> </ul>	<ul style="list-style-type: none"> <li>Electrostatic Precipitators</li> <li>Fabric Filters</li> <li>Associated parts and upgrade and repair services</li> <li>Engineering studies</li> <li>Field advisory services and training</li> </ul>	<ul style="list-style-type: none"> <li>Offer Selective Catalytic Reduction (SCR) technology licensed through Termokimik</li> <li>Reduces more than 90% of NO<sub>x</sub> from flue gas emissions and showcases a solid installation base around the world</li> </ul>

\* FGD upgrade and associated services are not included in the total megawatt listing to avoid duplicity.



# Wet Scrubber Design Capabilities

- $\text{SO}_2$  – Sulfur Dioxide - Will be readily absorbed
  - 95+% removal efficiency
  - Converted to Ammonium Sulfate
- $\text{HCl}$  – Hydrogen Chloride - Will be easily absorbed
  - 99+% removal efficiency
  - Converted to Ammonium Chloride
- $\text{F}$  – Hydrogen Fluoride - Will be easily absorbed
  - 99+% removal efficiency
  - Converted to Ammonium Fluoride
  - High solubility
- $\text{SO}_3$ – Sulfur Trioxide - Will be partially absorbed
  - ~20-50% removal efficiency
  - Converted to an Ammonium Sulfate Aerosol
- Fly Ash - Will be partially removed
  - ~30-70% removal efficiency
  - Can impact Product Purity



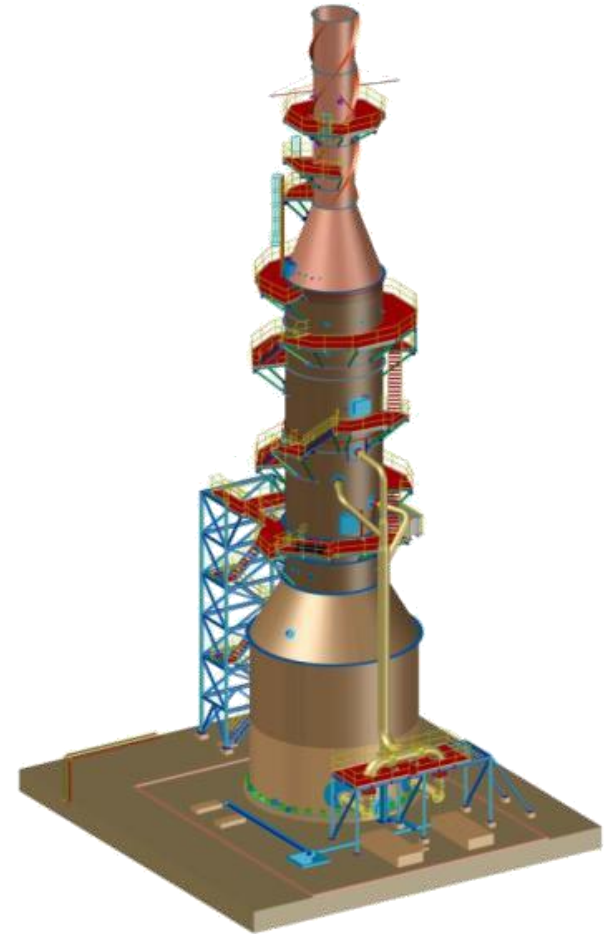
# AGENDA

Overview of the WFGD  
Process

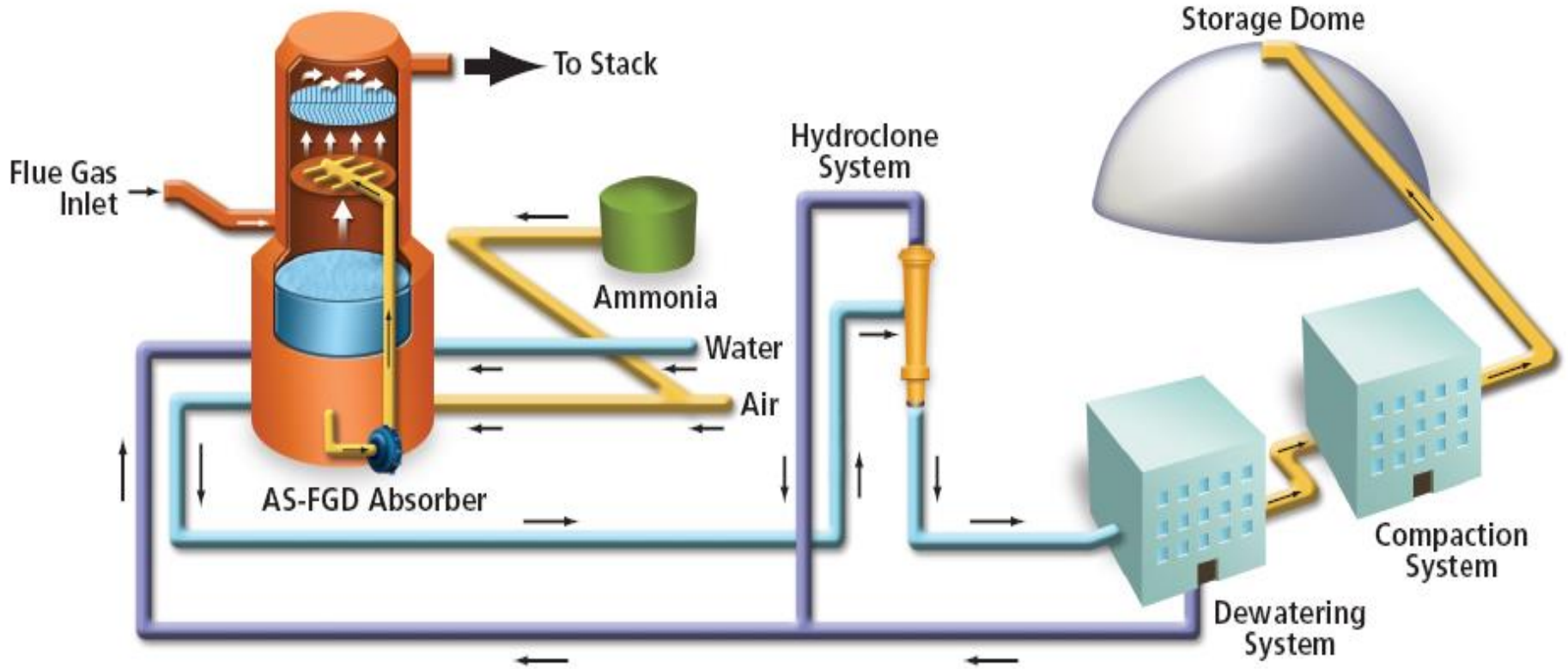
Basic Chemistry

Typical FGD Processes

Summary



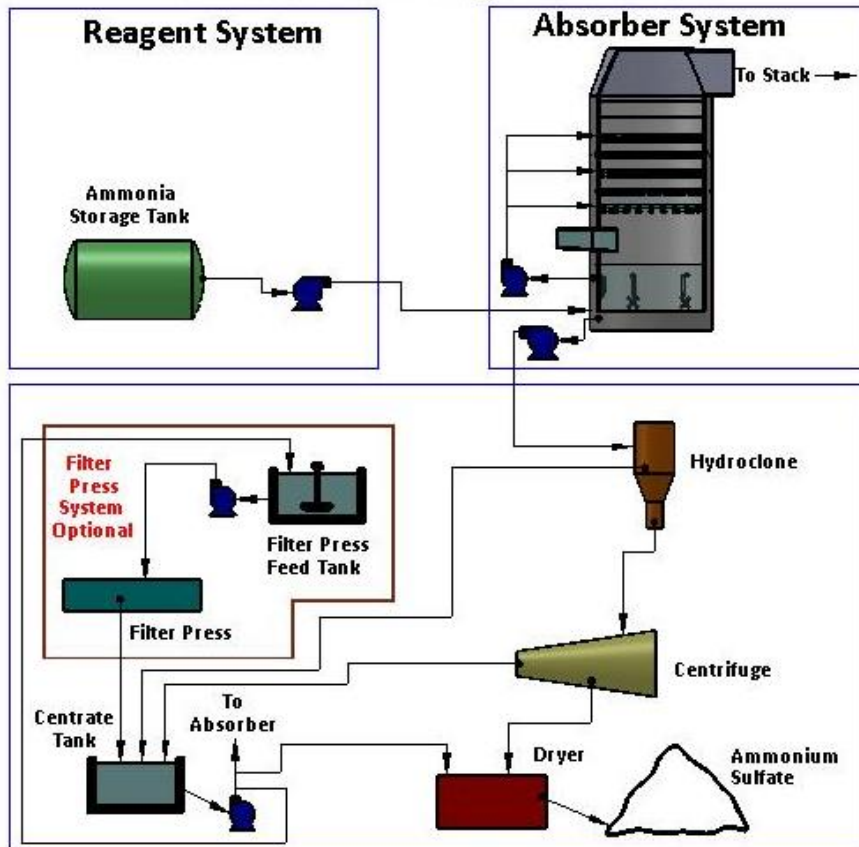
# Ammonium Sulfate Process





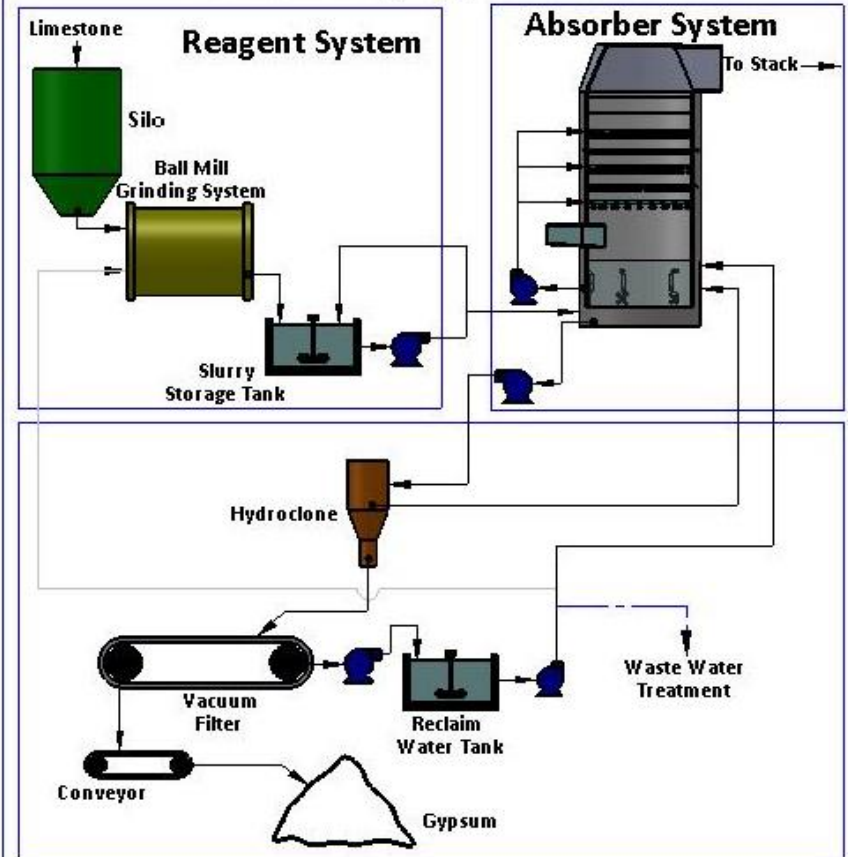
# Same Proven Equipment – Different Reagent

## Ammonium Sulfate Process



Ammonium Sulfate Dewatering

## Limestone/Gypsum Process



Gypsum Dewatering

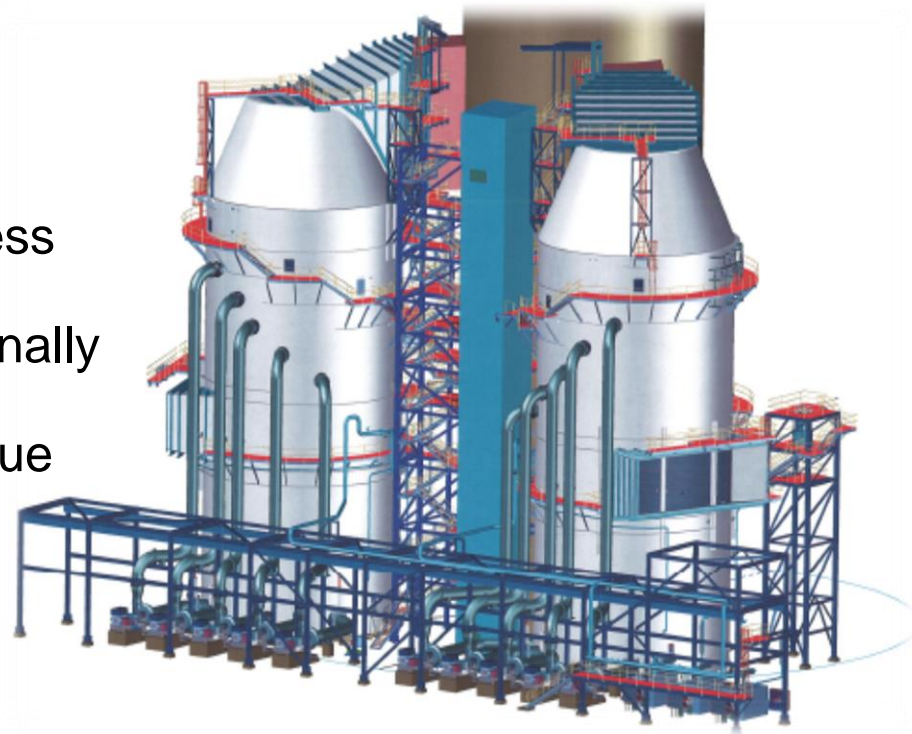




## FGD Reagent comparison

### **Gaseous SO<sub>2</sub> is convert to either a solid by-product or a liquid waste stream**

- Sodium - Throwaway process
  - Sodium Sulfite or Sulfate
    - No commercial Value
- Calcium - Gypsum Based process
  - Most widely used internationally
    - Byproduct marginal value
- Ammonia – Ammonium Sulfate
  - Commercial Fertilizer



## Advantages of MET Ammonium Sulfate Process

- Commercially proven for over 2 decades
  - AS FGD system designed with standard equipment redundancy
- Site specific economics including offset of operating costs, potentially lower fuel costs, lower capital costs
- Ammonia scrubber typically does not generate a purge stream to WWT
- Ammonia scrubber produces high value byproduct versus low value gypsum or sulfite waste sludge



## Ammonium Sulfate Process

### Offers significant advantages over traditional flue gas scrubbing

- Economics enhanced with low cost, high sulfur fuels
- Reduces/eliminates solid and liquid waste issues/costs
- Valuable AS fertilizer provides revenue stream
- No CO<sub>2</sub> greenhouse gas is produced in the AS FGD unlike conventional limestone FGD (where ~0.7 ton CO<sub>2</sub> is released per ton SO<sub>2</sub> absorbed.)



## ***Ammonia Sulfate Final Product***

***Compacted (Left) and Standard Product (Right)***

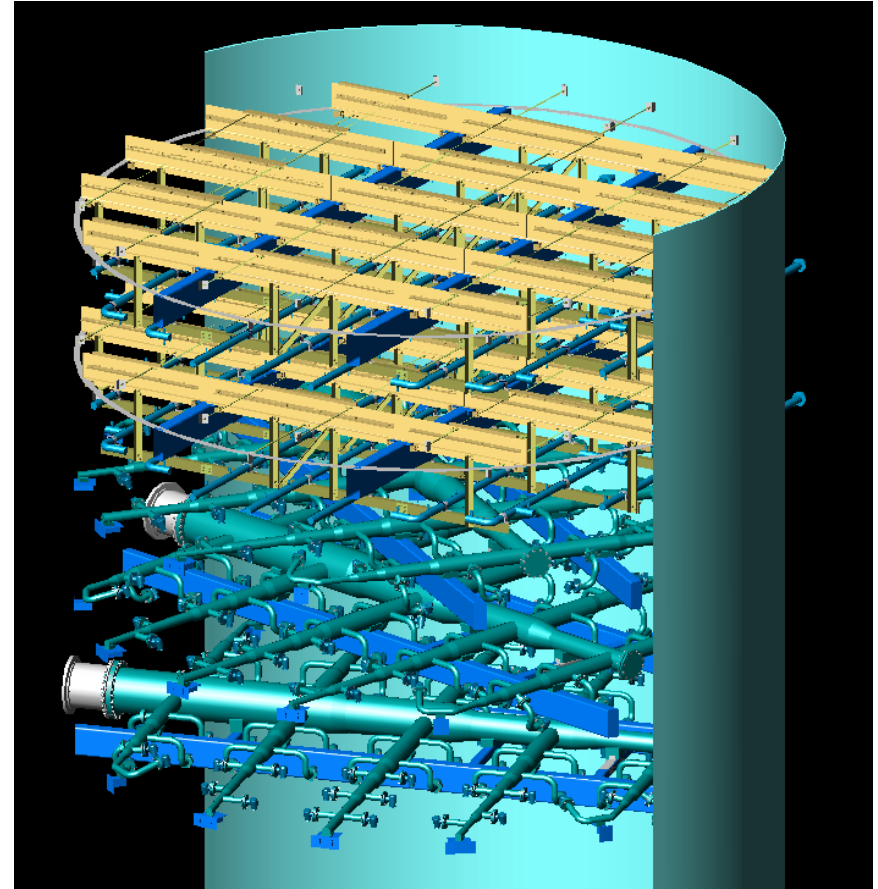


Overview of the WFGD  
Process

**Basic Chemistry**

Typical FGD Processes

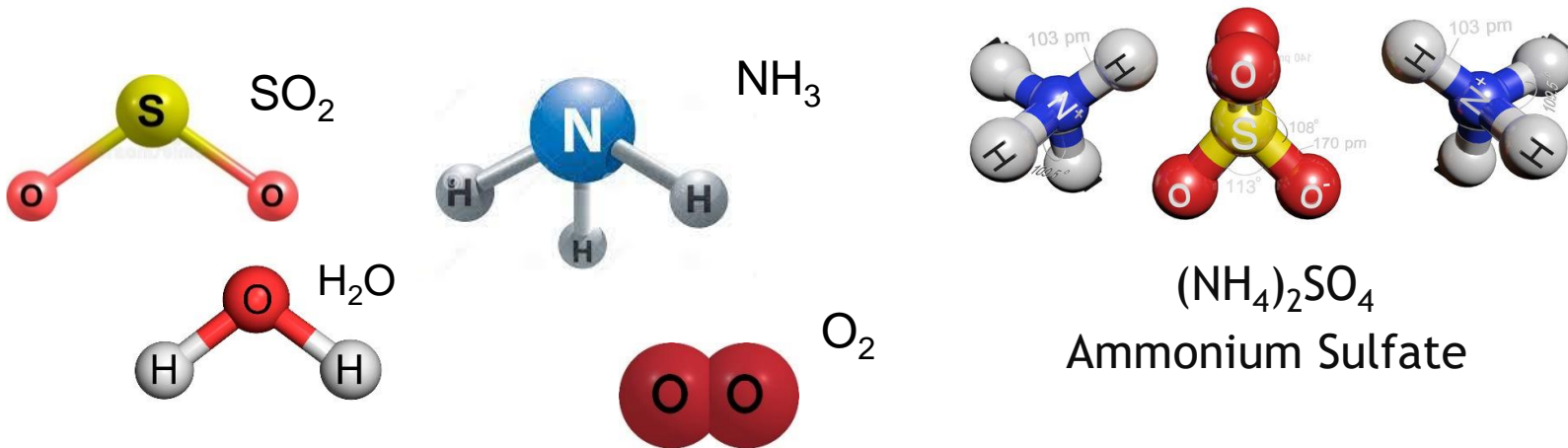
Summary



# Ammonia Sulfate Chemistry



- **For every Kilogram of SO<sub>2</sub> removed:**
  - ~One-half kilograms of Ammonia reagent consumed
  - ~Two kilograms of marketable Ammonium Sulfate produced
- **One kilogram of Ammonia** generates ~four kilograms of Ammonium Sulfate fertilizer





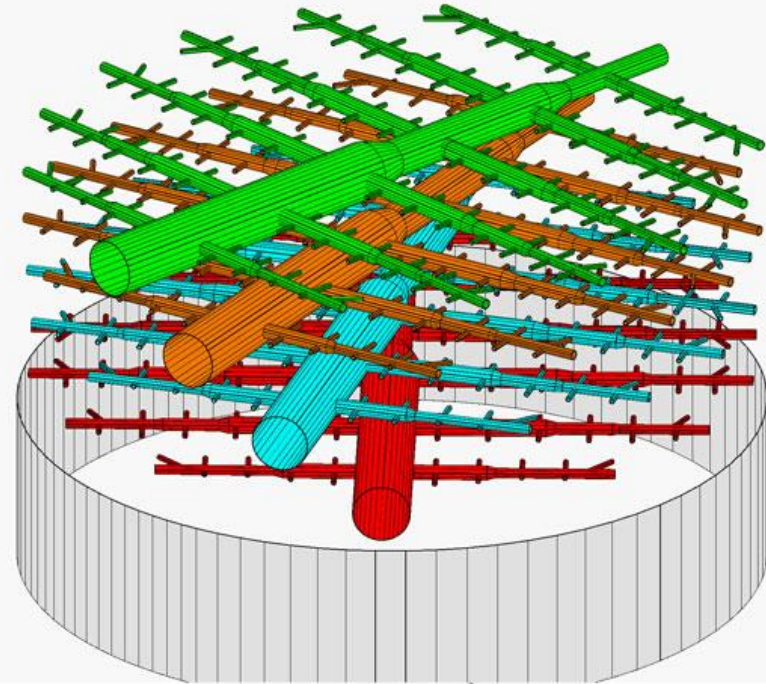
# Wet Scrubber Fundamentals

Overview of the WFGD  
Process

Basic Chemistry

**Typical WFGD  
Processes**

Summary





# Typical Absorber Design Considerations

## Open Spray Tower Design Considerations

- Outlet Emission Required
  - SO<sub>2</sub>
  - Particulate
  - Ammonia
- Nominal 3.0 – 4.0 mps saturated gas velocity in tower
- Recycle Residence Time - minimum of 3.5 minutes
- Minimum Oxidation Stoichiometry of 2



# Typical WFGD Design

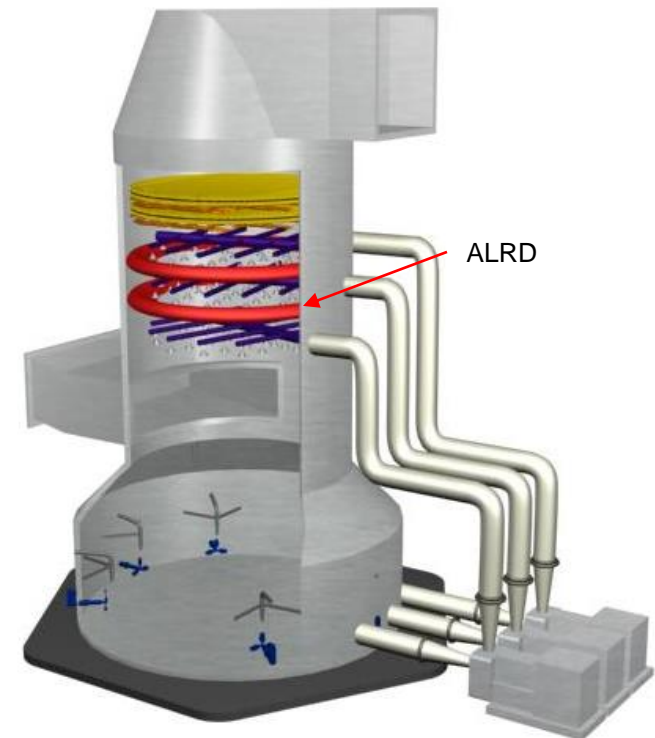
## *Operations and Design*

### Operations

- Gas distribution & wet/dry interface at Inlet
- Gas-Liquid contact in spray zone
- ALRD – Wall Rings
- Liquid-Gas separation with mist eliminators
- Oxidation & dissolution in reaction tank

### System Design

- Low lifecycle cost
- High availability



# Ammonia Sulfate Final Product

## Purity - 99+%

- Nitrogen - 21.0 - 21.1%
- Sulfur - 24.0 - 24.2%
- Water Insoluble Matter - < 0.1%
- Color - White to Beige
- Heavy Metals - < 10 ppm

**Exceeds Fertilizer Specifications**

## Residual Moisture

- Multiple Drying Steps
- Less Than 1.0 wt% Moisture
- Coated with Anti-caking Agent

**Excellent Storage & Handling**

## Particle Size

- 1.0 mm - 3.5 mm
- 240 - 275 SGN
- Uniformity Index - 45 - 50

**Ideal for Bulk Blending & Direct Application**

## Hardness

- Demonstrated Compaction Technology
- Expertise in Product Hardening Technology
- 1 - 3% Attrition in Industry Test

**Can be Handled and Transported Without Generating Dust**



Overview of the WFGD  
Process

Basic Chemistry

Typical WFGD Processes

Summary



# Dakota Gasification Company

## 350 MW equivalent / Ammonium Sulfate WFGD

DGC is a subsidiary of Basin Electric and was a partner in the first commercial application of MET's patented ammonium sulfate FGD technology. DGC selected the MET process over conventional limestone scrubbing.



Dakota Gasification Company  
North Dakota

<b>Fuel:</b>	<b>Heavy Residue</b>
<b>% Sulfur:</b>	<b>5.0% Design</b>
<b>Inlet Gas Volume: (acfm)</b>	<b>1,187,000</b>
<b>Reagent:</b>	<b>Ammonia</b>
<b>Design AS Production (Ton/year):</b>	<b>145,000</b>
<b>SO<sub>2</sub> Removal Efficiency:</b>	<b>98%</b>
<b>Absorber Type:</b>	<b>Spray Tower</b>
<b>AS-FGD Start-up</b>	<b>1996</b>



# Syncrude – Alberta Canada

**315 MW equivalent / Ammonium Sulfate WFGD**



UE-1 Expansion Plant  
Alberta, Canada

<b>Source:</b>	<b>Coker/CO boiler offgas</b>
<b>Scope:</b>	<b>Ammonia FGD &amp; fertilizer plant</b>
<b>Inlet Gas Volume: (acfm)</b>	<b>1,300,000</b>
<b>Byproduct:</b>	<b>109,000 te/yr granular AS fertilizer</b>
<b>Absorber Type:</b>	<b>Spray Tower</b>
<b>SO<sub>2</sub> Removal Efficiency:</b>	<b>95+%</b>
<b>Startup Date:</b>	<b>2006</b>
<b>Fertilizer Plant:</b>	<b>Built, owned, operated and maintained by Marsulex Inc. until sold to Chemtrade Logistics</b>





# SINOPEC - China

## 2 x 200 MW / Ammonium Sulfate WFGD



Qilu Thermal Plants  
Shandong Province, China

<b>Fuel:</b>	<b>Coal Fired Boiler</b>
<b>Scope:</b>	<b>EPC</b>
<b>Inlet Gas Volume:</b>	<b>1,162,547 Kg/Hr</b>
<b>Absorber Type:</b>	<b>Open Spray Tower</b>
<b>SO<sub>2</sub> Removal Efficiency:</b>	<b>98%</b>
<b>Startup Date:</b>	<b>Unit 2: Jul '09 Unit 1: Sep '09</b>
<b>Byproduct:</b>	<b>Standard Grade Ammonium Sulfate</b>





# Zakłady Azotowe Pulawy Poland



Combined Heating and Power Plant | Pulawy,  
Poland

<b>Source:</b>	<b>Coal-Fired Boilers 300 MW</b>
<b>Scope:</b>	<b>Technology, engineering, key components and field services</b>
<b>Inlet Gas Volume:</b>	<b>1,365,000 acfm 1,457,000 Nm<sup>3</sup>/hr</b>
<b>Byproduct:</b>	<b>Ammonium Sulfate Fertilizer</b>
<b>Absorber Type:</b>	<b>Open Spray Tower</b>
<b>SO<sub>2</sub> Removal Efficiency:</b>	<b>&gt;93.5%</b>
<b>Scheduled Startup Date:</b>	<b>4<sup>th</sup> Quarter 2011</b>



# Groupa Azoty Police Poland



<b>Source:</b>	<b>Coal-Fired Boilers 110 MW</b>
<b>Scope:</b>	<b>Technology, engineering, key components and field services</b>
<b>Inlet Gas Volume:</b>	<b>504,000 ACFM 538,000 Nm<sup>3</sup>/hr</b>
<b>Byproduct:</b>	<b>Ammonium Sulfate Fertilizer</b>
<b>Absorber Type:</b>	<b>Open Spray Tower</b>
<b>SO<sub>2</sub> Removal Efficiency:</b>	<b>&gt;95%</b>
<b>Startup Date:</b>	<b>2017</b>



# Sanders Lead Smelter - Alabama



<b>Source:</b>	<b>Lead Smelter OFF Gas Equivalent 50 MW gas flow</b>
<b>Scope:</b>	<b>Technology, engineering, key components and field services</b>
<b>Inlet Gas Volume:</b>	<b>220,000 ACFM 252,000 Nm3/hr</b>
<b>Byproduct:</b>	<b>Ammonium Sulfate Fertilizer</b>
<b>Absorber Type:</b>	<b>Open Spray Tower</b>
<b>SO<sub>2</sub> Removal Efficiency:</b>	<b>&gt;95%</b>
<b>Startup Date:</b>	<b>2019</b>



