Advanced Ammonium Sulfate Wet FGD

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Proprietary Ammonia-based FGD
Ammonium Sulfate Process (AS-FGD)

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\(_2\) greenhouse gas is produced in the AS FGD unlike conventional limestone FGD (where ~0.7 ton CO\(_2\) is released per ton SO\(_2\) absorbed.)
Proprietary AS-FGD

Ammonium Sulfate Process
Process Comparison | Limestone vs. AS-FGD

Same Proven Absorber – Different Reagent and Dewatering

Ammonium Sulfate Process

Reagent System

Ammonia Storage Tank

Absorber System

To Stack

Filter Press Feed Tank

Filter Press

Centrate Tank

To Absorber

Dryer

Ammonium Sulfate

Ammonium Sulfate Dewatering

Limestone/Gypsum Process

Reagent System

Limestone

Silo

Ball Mill Grinding System

Slurry Storage Tank

Absorber System

To Stack

Gypsum

Vacuum Filter

Reclaim Water Tank

Waste Water Treatment

Hydroclone

Conveyor

Gypsum Dewatering
MET AS-FGD

Compacted (Left) and Standard 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*

**Particle Size**
- 1.0 mm - 3.5 mm
- 240 - 275 SGN
- Uniformity Index - 45 - 50

*Ideal for bulk blending & direct application*

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

*Excellent storage & handling*

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

*Can be easily handled and transported*
MET AS-FGD

Reagent Effectiveness – Ammonia vs. Limestone

Comparison is based on open spray tower with ALRD® installations. AS-FGD requires less L/G than limestone FGD for a given removal efficiency.
SO₂ + 2NH₃ + H₂O → (NH₄)₂SO₃ (1)

(NH₄)₂SO₃ + 1/2 O₂ → (NH₄)₂SO₄ (2)

- For every part (mass unit) of SO₂ removed:
  - One-half part Ammonia is consumed
  - Two parts of Ammonium Sulfate is produced

- One part of Ammonia generates four parts of Ammonium Sulfate fertilizer

- Ammonium Sulfate Production -
  - 100 tpy per % Sulfur per MW
MET AS-FGD

Reagent and Product Historical Price Trend in the United States
A 600 MW Unit’s Ammonium Sulfate Production
50,000 tpy per % Percent Fuel Sulfur

Assume NH₃ and AS market pricing results in a positive differential of $100/ton average of AS produced:

- $10MM/year for 2% sulfur fuel
- $20MM/year for 4% sulfur fuel

Site-specific factors such as actual source/cost NH₃, market price of AS, unit load factor, fuel costs, transportation, etc., need to be factored.
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**

**350 MWe | Ammonium Sulfate WFGD**

- Fuel: Heavy Residue
- % Sulfur: 5.0% Design
- Inlet Gas Volume: (acfm): 1,187,000
- Reagent: Ammonia
- Design AS Production (Ton/year): 145,000
- \(\text{SO}_2\) Removal Efficiency: 98%
- Absorber Type: Spray Tower
- AS-FGD Start-up: 1996
## MET AS-FGD

### DGC Tested Performance vs. Guarantee Level

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Units</th>
<th>Guarantee</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂ Removal Efficiency</td>
<td>%</td>
<td>93</td>
<td>95-98+</td>
</tr>
<tr>
<td>Ammonia Slip</td>
<td>ppmv, wet</td>
<td>&lt;10</td>
<td>3-10</td>
</tr>
<tr>
<td>AS Product Purity</td>
<td>wt %</td>
<td>≥99.0</td>
<td>99.5</td>
</tr>
<tr>
<td>AS Product Moisture Content</td>
<td>wt %</td>
<td>&lt;1.0</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>AS Product Hardness</td>
<td>%</td>
<td>&lt;5</td>
<td>1-2</td>
</tr>
<tr>
<td>Size Guide Number</td>
<td>-</td>
<td>240-290</td>
<td>250-280</td>
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</table>
DakSul 45® AS product specification can be located [http://www.dakotagas.com/](http://www.dakotagas.com/)
## Syncrude UE-1 Upgrade Complex

**315 MWe | Ammonium Sulfate WFGD**

<table>
<thead>
<tr>
<th>Source:</th>
<th>Coker/CO boiler offgas</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scope:</strong></td>
<td>Ammonia FGD &amp; fertilizer plant</td>
</tr>
<tr>
<td><strong>Inlet Gas Volume:</strong> (acfm)</td>
<td>1,300,000</td>
</tr>
<tr>
<td><strong>Byproduct:</strong></td>
<td>109,000 te/yr granular AS fertilizer</td>
</tr>
<tr>
<td><strong>Absorber Type:</strong></td>
<td>Spray Tower</td>
</tr>
<tr>
<td><strong>SO₂ Removal Efficiency:</strong></td>
<td>95+%</td>
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<tr>
<td><strong>Startup Date:</strong></td>
<td>2006</td>
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</table>

**UE-1 Expansion Plant**
Alberta, Canada
## Proprietary Ammonium Sulfate FGD

### Syncrude Performance vs. Guarantees

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Units</th>
<th>Guarantee</th>
<th>Performance</th>
</tr>
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<tbody>
<tr>
<td>SO₂ Removal Efficiency</td>
<td>%</td>
<td>93</td>
<td>95-98+</td>
</tr>
<tr>
<td>Ammonia Slip</td>
<td>ppmv, wet</td>
<td>&lt;10</td>
<td>3-7</td>
</tr>
<tr>
<td>Opacity</td>
<td>%</td>
<td>&lt;4% from NH₃</td>
<td>0% from NH₃</td>
</tr>
<tr>
<td>Pressure Drop</td>
<td>inches w.c.</td>
<td>&lt;11</td>
<td>7 - 8</td>
</tr>
<tr>
<td>AS Product Purity</td>
<td>wt %</td>
<td>&gt;99.0</td>
<td>99.5</td>
</tr>
<tr>
<td>AS Product Moisture</td>
<td>wt %</td>
<td>&lt;1.0</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Size Guide Number</td>
<td>-</td>
<td>240-290</td>
<td>240-260</td>
</tr>
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</table>
## SINOPEC - Qilu

### 2 x 200 MW | Ammonium Sulfate WFGD

<table>
<thead>
<tr>
<th>Fuel:</th>
<th>Coal</th>
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</thead>
<tbody>
<tr>
<td>Scope:</td>
<td>EPC</td>
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<tr>
<td>Inlet Gas Volume: (acfm)</td>
<td>1,162,547 Kg/Hr</td>
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<td>Absorber Type:</td>
<td>Open Spray Tower</td>
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<tr>
<td>SO₂ Removal Efficiency:</td>
<td>98%</td>
</tr>
<tr>
<td>Startup Date:</td>
<td>Unit 2: Jul ‘09</td>
</tr>
<tr>
<td></td>
<td>Unit 1: Sep ‘09</td>
</tr>
<tr>
<td>Byproduct:</td>
<td>Standard Grade Ammonium Sulfate</td>
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</table>

Qilu Thermal Plants  
Shandong Province, China
**Zaklady Azotowe Pulawy**

**300 MW**

<table>
<thead>
<tr>
<th>Source:</th>
<th>Coal-Fired Boilers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope:</td>
<td>Technology, engineering, key components and field services</td>
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<tr>
<td>Inlet Gas Volume: (acfm)</td>
<td>1,365,000</td>
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<tr>
<td>Byproduct:</td>
<td>Ammonium Sulfate Fertilizer</td>
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<tr>
<td>Absorber Type:</td>
<td>Open Spray Tower</td>
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<tr>
<td>SO(_2) Removal Efficiency:</td>
<td>&gt;93.5%</td>
</tr>
<tr>
<td>Scheduled Startup Date:</td>
<td>2012</td>
</tr>
</tbody>
</table>

Combined Heating and Power Plant | Pulawy, Poland
Advantages of MET Ammonium Sulfate Process

- Commercially proven for over a decade
- 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