

Reinhold Environmental Ltd.



2006 APC Round Table & Expo Presentation

July 16-18, 2006, Columbus, OH

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Wet Flue Gas Desulfurization Process Ammonia / Ammonium Sulfate Systems

2006 APC Round Table & Expo and APC PCUG Meeting
Hyatt Regency Columbus
Columbus, Ohio
July 2006

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New Market Factors Drove Ammonia Technology Development

Emissions trading mechanisms created new “competition”

- ***USA’s Clean Air Act Amendments of 1990 created “emissions trading” mechanism***
- ***Utilities’ true cost of SO₂ emissions, absent local or extraordinary regulations, became “the value of credits on the market”***
- ***Credits reached relatively low levels of approximately US\$ 63 per ton in the 1990’s***
- ***This low cost of “compliance” established a very high, competitive “bar” for conventional FGD technologies***
- ***A new approach was needed, one which could compete with low emission credit values***

Marsulex (then General Electric) developed and commercialized an improved version of ammonia scrubbing technology

***MLX Ammonium Sulfate FGD Technology Meets
Competitive Challenge by Lowering Compliance Costs***

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Ammonia Scrubbing Basis of Design

First Generation Ammonia Systems

- ***First Attempts At Ammonia Scrubbing Utilized High Ammonia Reactivity Resulting in Very Aggressive Absorber Designs - pH, L/G, Absorber Size***
- ***As a Result, Early Generation Ammonia Scrubbers Resulted Very High Ammonia Slip and High Opacity Issues***
- ***Higher pH's and Incomplete Oxidation Produce Free Ammonia in the Gas Phase***

MLX Ammonia Scrubbing Process

- ***MLX Demonstrated and Patented Optimum Operating Range to Minimize Ammonia Slip And Opacity***
- ***Free Ammonia in the Gas Phase Determines opacity Levels and is a function of Three Process Parameters; pH, Degree of Oxidation and Ammonia Injection Methods***
- ***MLX Demonstrated Minimal Gas Phase Ammonia and Zero Impact on Opacity From Ammonia and Ammonium Salts***

Essence of MLX Patents Ensures Operation In Optimum pH Range, Complete Oxidation and Optimum Ammonia Injection Methods



Ammonia Scrubbing Technology Summary

Ammonia Scrubbing Development History:

1985-87	<i>Developed bench-scale ammonia scrubbing technology</i>
1987	<i>GEESI awarded first ammonia scrubbing patent</i>
1992-93	<i>10 MW pilot demonstrated for two modes of operation</i>
1994	<i>Awarded commercial contract with DGC</i>
1994	<i>Second ammonia scrubbing patent awarded</i>
1996-97	<i>Startup and successful demonstration of 350 MW eq. Ammonia scrubbing with production of granular ammonium sulfate</i>
1997	<i>Marsulex purchased substantially all the assets of GEESI</i>
1998	<i>Applied for three (3) additional patents</i>

Commercial NH₃ System Performance at DGC:

Design Parameter	Guarantee	Performance
SO ₂ Removal Efficiency	93%	95-98+%
Ammonia Slip, ppm	< 10	3 – 7
Opacity	<4% from NH ₃	0% from NH ₃
Pressure Drop, "WC	< 11	7 – 8
Purity, %	99	99.5
Moisture, wt%	< 1.0	< 0.1
Hardness, %	< 5	1 – 2
Size Guide Number	240 – 290	240 - 260

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Ammonium Sulfate Process Chemistry



- *For every ton of SO₂ removed:*
 - *Need one-half ton of Ammonia*
 - *Produces two tons of Ammonium Sulfate*
- *One ton of Ammonia generates four tons of Ammonium Sulfate*

Economic leverage derived from the 4:1 production ratio between ammonium sulfate and feed stock ammonia



Ammonia Conversion Process

- ***Production of Ammonium Sulfate requires:***
 - ***Sulfur - Free in flue gas***
 - ***Ammonia - \$380 - \$460 / ton***
 - ***Energy - Evaporative Energy Free in MET Process***

- ***One Ton Ammonia is Converted to Four Tons Ammonium Sulfate***

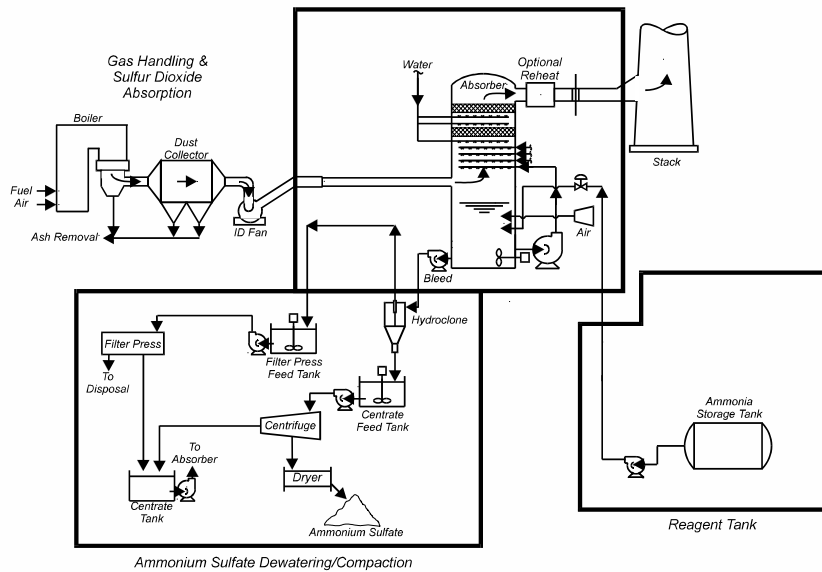
- ***Ammonium Sulfate - \$175 - \$200 / ton***

MET Process Increases Value of Ammonia 70% - 400%

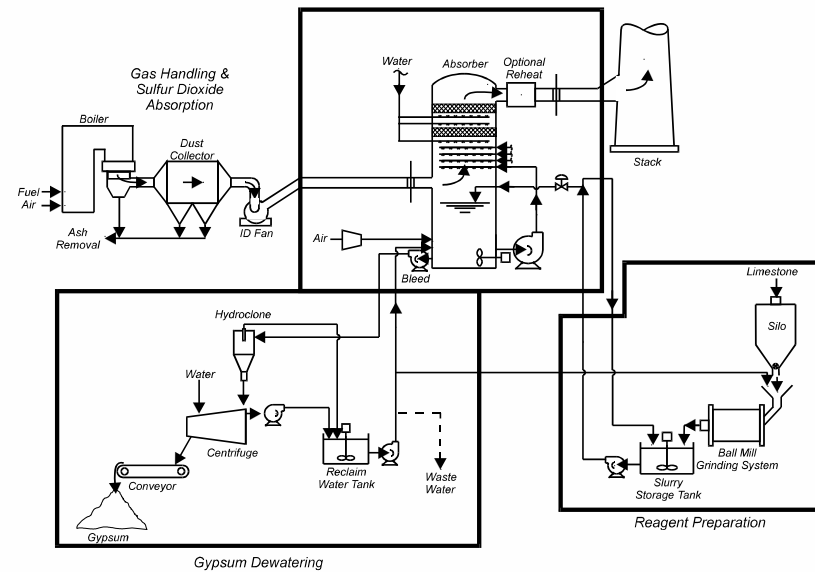


Process Comparison

Ammonium Sulfate Process



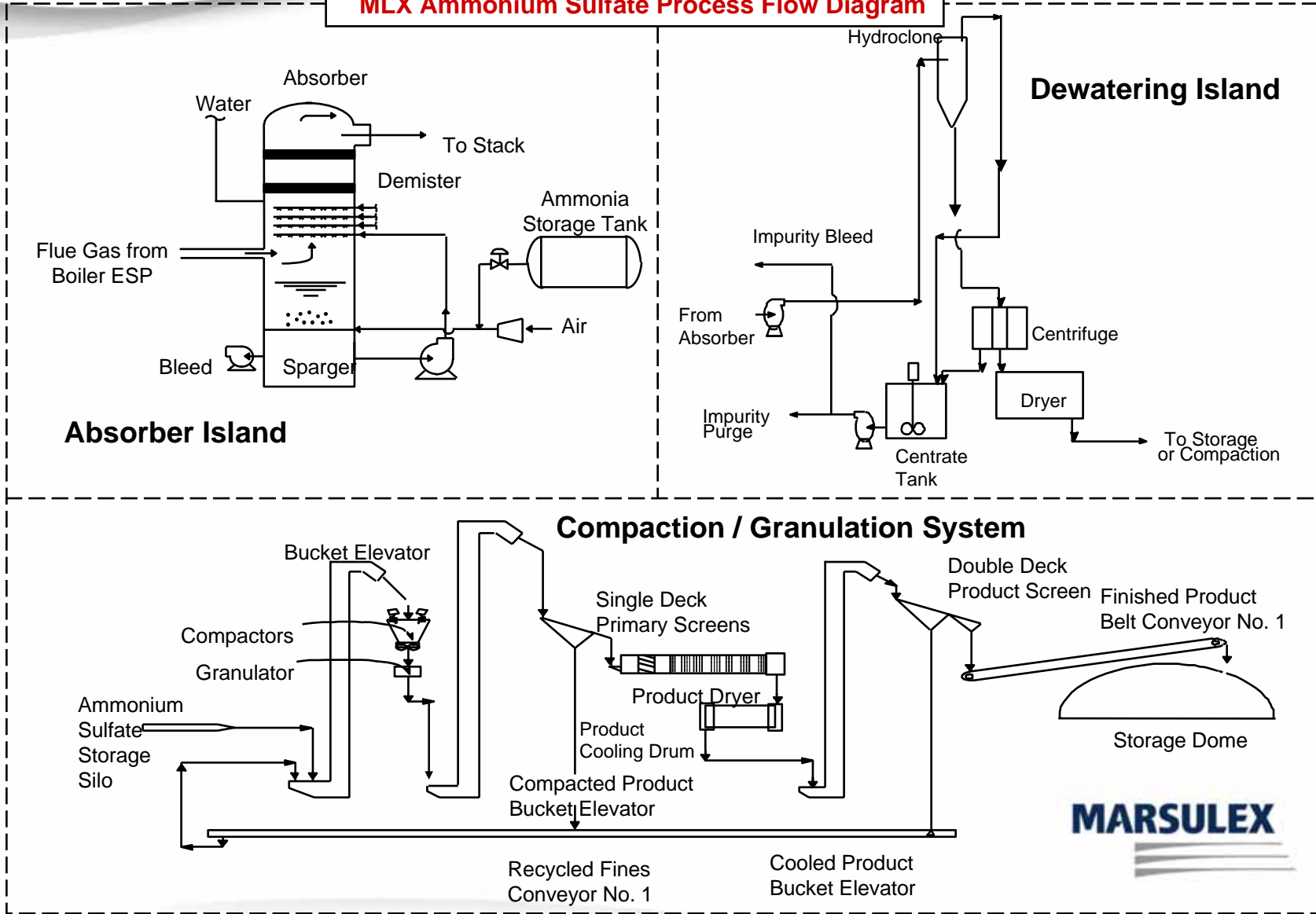
Limestone/Gypsum Process



Based on Proven Equipment - Different Reagent

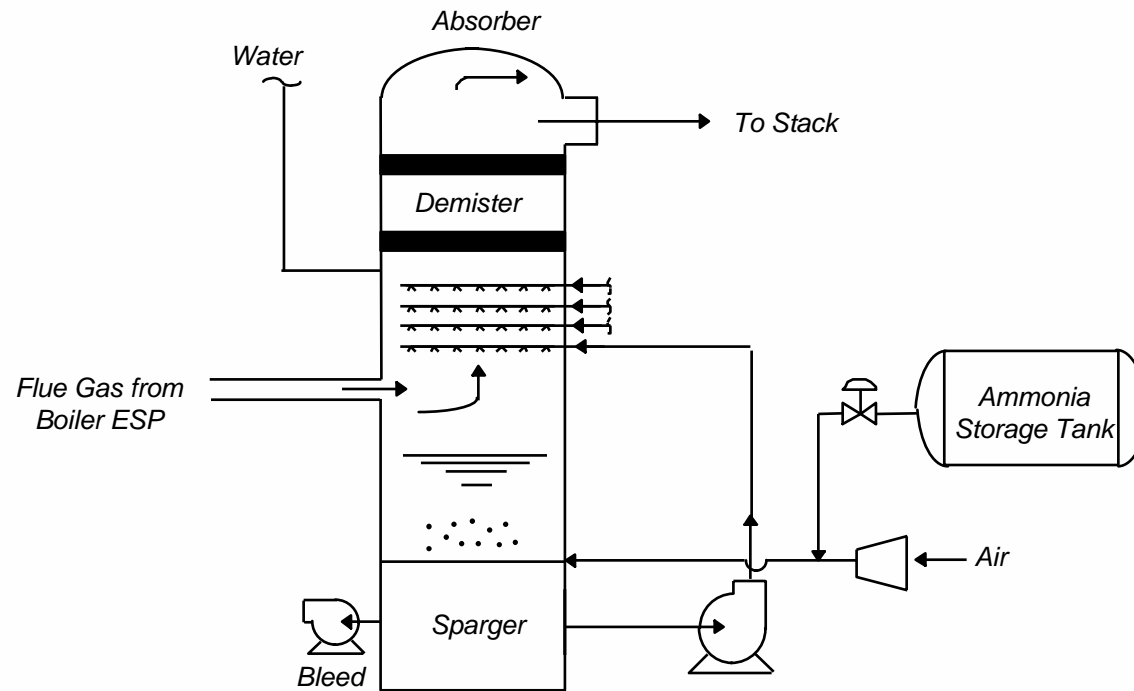


MLX Ammonium Sulfate Process Flow Diagram



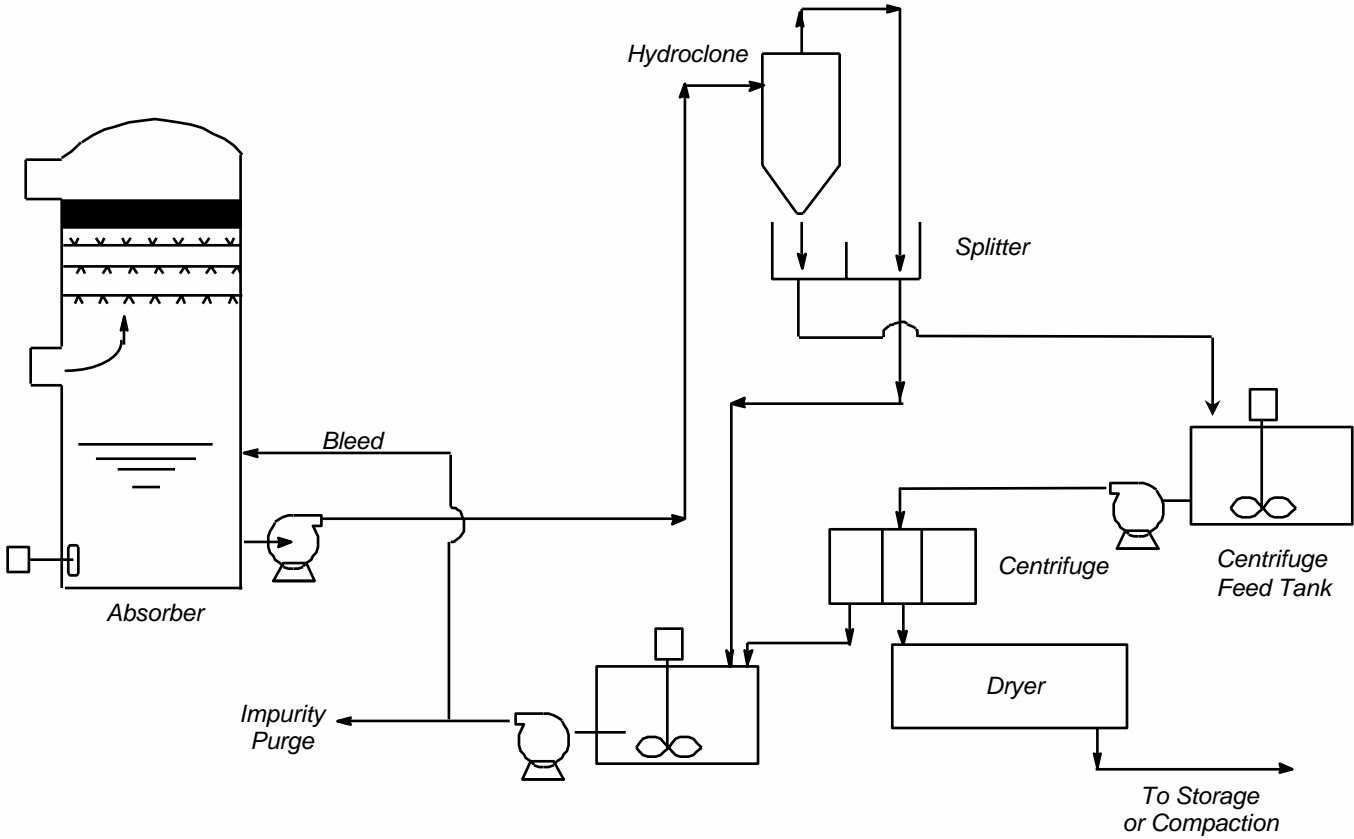


MLX Ammonium Sulfate Process Absorber Island



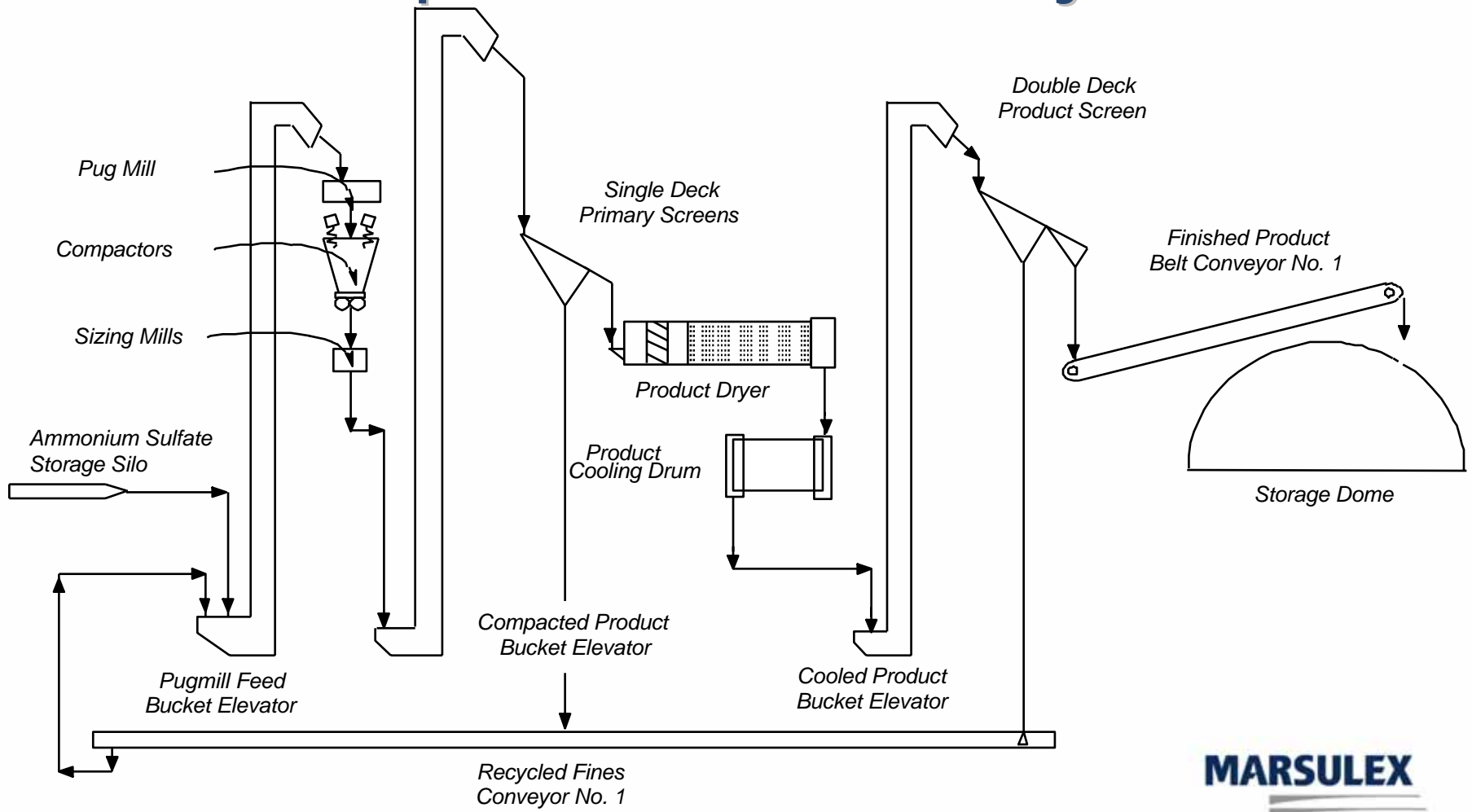


MLX Ammonium Sulfate Process Dewatering System



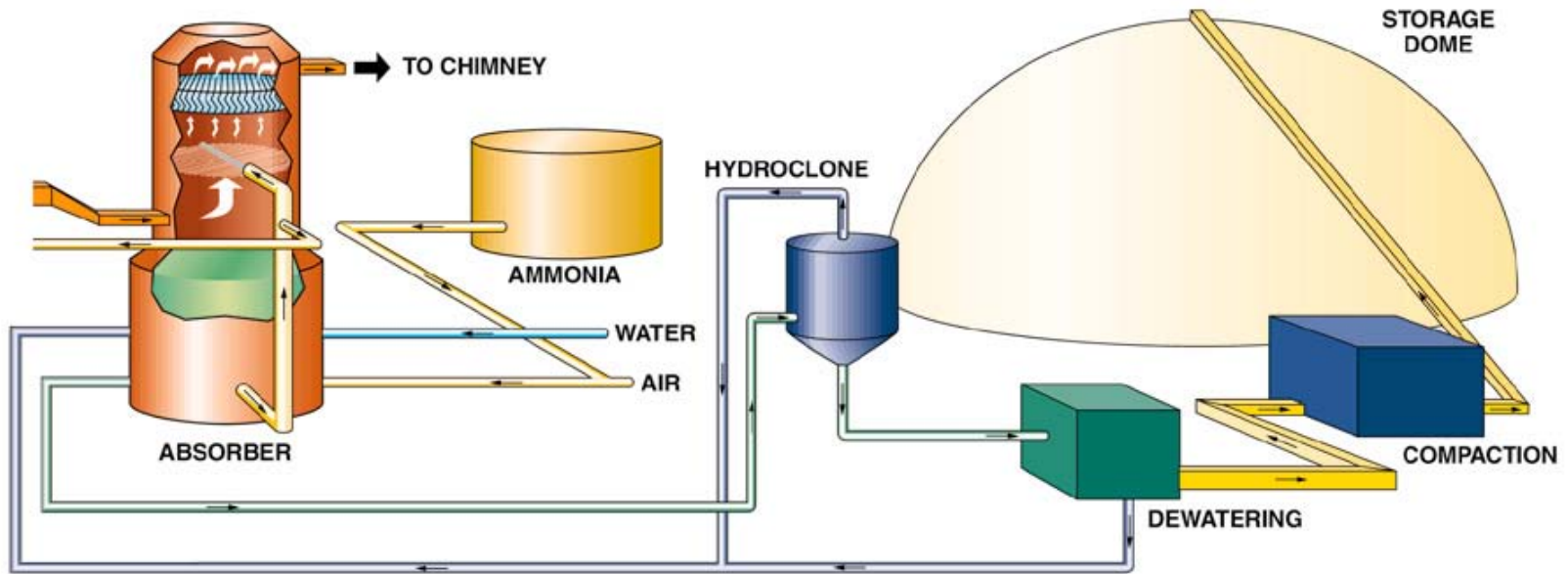


MLX AS Compaction Granulation System





The Marsulex Ammonium Sulfate Process



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Dakota Gasification Company, North Dakota Great Plains Synfuels Plant, 350 MW



Fuel.....Heavy Resid.
% Sulfur.....5.0%
Inlet Gas Volume
(acfm).....1,187,000
Reagent.....Ammonia
Absorber Type.....Spray Tower
SO₂ Efficiency Capability....98+%
Startup Date.....1996

The DGC subsidiary of Basin Electric is a partner in the first application of MLX's patented ammonium sulfate FGD technology. This process produces a high value byproduct which can generate a positive revenue stream for the Owner, thus offsetting a portion of the operating expenses of the system. DGC selected the MLX process over conventional limestone scrubbing.





Marsulex AS Fertilizer Plant at Ft. McMurray, Alberta, Canada



Project:	Ammonia FGD and Fertilizer Plant
Location:	Fort. McMurray, Alberta, Canada
Technology:	Marsulex's proprietary ammonia-based FGD
Reagent:	Customer-generated waste ammonia stream
Technical:	Treatment of over 1.2 million cfm of Coker / CO boiler offgas to reduce SO₂ emissions and produce a high quality granular ammonium sulfate fertilizer byproduct <ul style="list-style-type: none">• 95% SO₂ removal efficiency• 109k te/yr of granular fertilizer produced• Utilization of 28k te/yr of waste byproduct ammonia
Commercial Structure	Client owns and operates absorber/gas path; Marsulex owns and operates fertilizer plant
Benefits:	<ul style="list-style-type: none">• High SO₂ reduction efficiency• Precludes future NOx emissions as a result of eliminating ammonia combustion• Low operating costs• Saleable ammonium sulfate fertilizer byproduct
Start Up Date:	mid-2006





Advantages of the MLX Ammonia Scrubbing Process

- *A / AS FGD system designed with standard conventional critical equipment redundancy*
- *Ammonium sulfate water soluble chemistry prevents any internal buildup versus scaling potential with limestone scrubbing*
- *Ammonia reagent more reactive than limestone, capable of achieving high 90s removal efficiency at unlimited sulfur contents*
- *Ammonia scrubber produces high value byproduct versus low value gypsum or sulfite waste sludge*
- *Reagent (limestone) utilization is very high and expensive at high sulfur fuel levels*
- *Ammonia scrubber operation more forgiving than limestone, particularly at high sulfur fuel levels*
- *Ammonia scrubber operated at slightly higher reliability / availability than limestone*
- *Ammonia scrubber is patented technology (process control patents)*



Benefits of Ammonium Sulfate

- *Non-Volatile Source of Nitrogen*
- *Sulfur is a Valuable Micro-Nutrient for Many Crops*
- *Increasing Sulfur Deficiency in Soils in Many Industrialized Nations*
- *Non-Explosive Source of Nitrogen*
- *Compaction System Ideal for Addition of Slow-Release Polymer*
- *As World Agricultural Market Moves to Blending, MLX Process is a Reliable Source of Granulated Product*

***MLX Process Controls Harmful Acid While
Producing Valuable Source of Sulfur for Soils***

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MLX Technology Enables a Comprehensive Approach

Full Integration with Boiler Unit & Fuel

- *Ammonia technology facilitates and encourages the use of higher sulfur fuels or fuel blends*
- *Higher sulfur fuels are typically priced lower per thermal unit of heat content than lower sulfur fuels*
- *Lower cost fuels enables utilities operators to reduce power generation costs*
- *Production of high quality, granular fertilizer makes maximum use of nitrogen/sulfur species*
- *Fertilizer granularization encourages customized blending & optimum crop feeding*
- *Ammonia technology reduces CO₂ emissions versus conventional technologies*
- *Enables a highly beneficial, synergistic approach to infrastructure integration*

***Marsulex AS Technology offers benefits to
Power Producers, Refineries & Infrastructure Planners***

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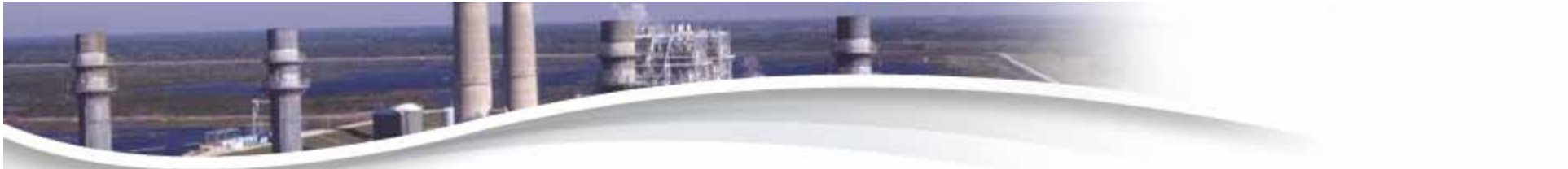

Ammonium Sulfate Market Drivers

- *Slow release polymer addition to MLX product expands market*
- *China utilizes > 2 million tons/yr of “S” bearing fertilizers*
- *Latin American market penetration*
- *Nitrogen premium market*
 - *Less volatile than Urea*
 - *Resistant to leaching*
 - *“N” & “S” work together*
 - *Non-explosive*
- *Sulfur premium*
 - *Crop yields can be doubled*
 - *1.2M tons of “S” or 4.8M tons of AS deficit in U.S. in 1995*
 - *6.6M tons of “S” deficit in world 1995*
 - *Growth rate of “S” demand is 3% per year in North America*
- *Crops can digest 1 lb. “S”/5 lbs. “N”; presently using 1/2 lb “S”/10 lbs. “N”*
- *Caprolactam process improvements reduce ammonium sulfate production*

Large Potential Ammonium Sulfate Market

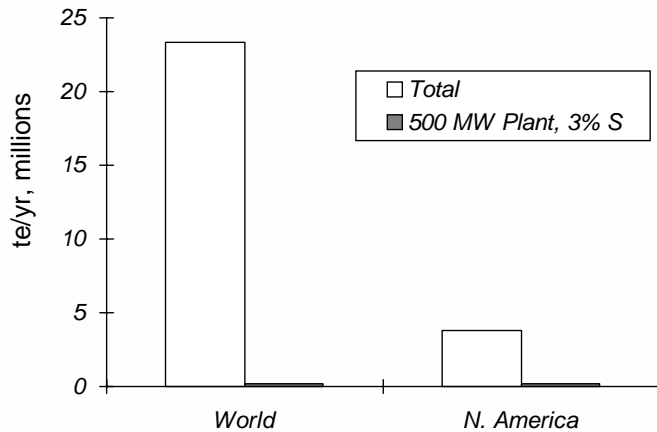
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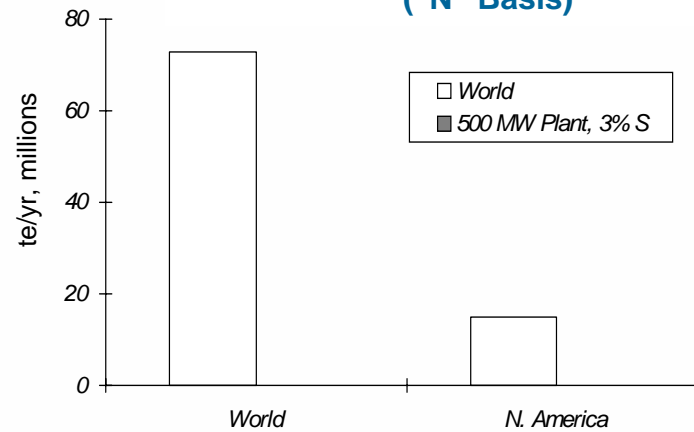


Ammonium Sulfate & Total Nitrogen (“N”) Basis

Ammonium Sulfate Capacity



Total Nitrogen Based Fertilizer Capacity (“N” Basis)



Conclusions:

- Each 500 MW ammonium sulfate plant (3% S) represents approximately 3% N. American capacity and 0.6% of world capacity
- Ammonium sulfate will compete with urea, ammonium nitrate and other nitrogen based fertilizers at its “floor” value (“N” content value only)
- Once competing at “N” value, each 500 MW plant represents only 0.2% of N. American capacity and 0.04% of world capacity

Nitrogen Market is a Solid Foundation for Ammonium Sulfate





Ammonium Sulfate Product Quality Characteristics

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 Standard

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**

High Quality Commercial Product!

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Optimizing the Value of Ammonium Sulfate FGD Product

Ammonium Sulfate is produced in two main forms:

- Standard grade crystals which are sugar-like in appearance*
- Granular product in the 1.0 – 3.5 mm size range depending on local preferences*
- *Standard grade can be used as feed material for ammoniated NPKS compounded products; limits application effectiveness for different crops & growing situations*
- *Granular product can be custom blended to meet exact needs of soils given their composition, previous crops and current year target crops*
- *Granular product enables farms to optimize the nutrients applied while minimizing the “non-effective” use of NPKS constituents*
- *FSU “maximum production” techniques over applied certain nutrients leading to serious runoff and water pollution problems*
- *Granularization techniques preclude the majority of such problems*

***MLX Use of Granularization Differentiates
and Maximizes the Market Value of AS***

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Marsulex AS Technology Services

Summary of Environmental Solutions:

Advantages of Marsulex AS scrubbing process:

- *Maximum available control technology (MACT) for Particulate, SO₂, Opacity and CO₂*
- *Greater than 98% SO₂ removal efficiency with unlimited “S” fuels*
- *Achieves > 99% reliability / availability*
- *Significant cost savings and NPV versus LSFO scrubbing*
- *Eliminates waste product disposal costs and potential liability*

Commercially Proven Technology:

- *18 years of AS technology success*
- *Ten years of commercial operation at Dakota Gasification (350 MW eq.)*
 - *Continuously exceeding performance guarantees*
 - *>99% availability / reliability*
 - *Producing highest purity / quality byproduct*
- *Commercial Acceptance in the Utility and Refinery marketplace*





MLX FGD Technology Solution

Ammonia Scrubbing:

- ***Lower Operational Costs than Limestone***
- ***No Chemical or Byproduct Waste Handling***
- ***Long-Term Environmental Compliance***
- ***High Quality Ammonium Sulfate Fertilizer***

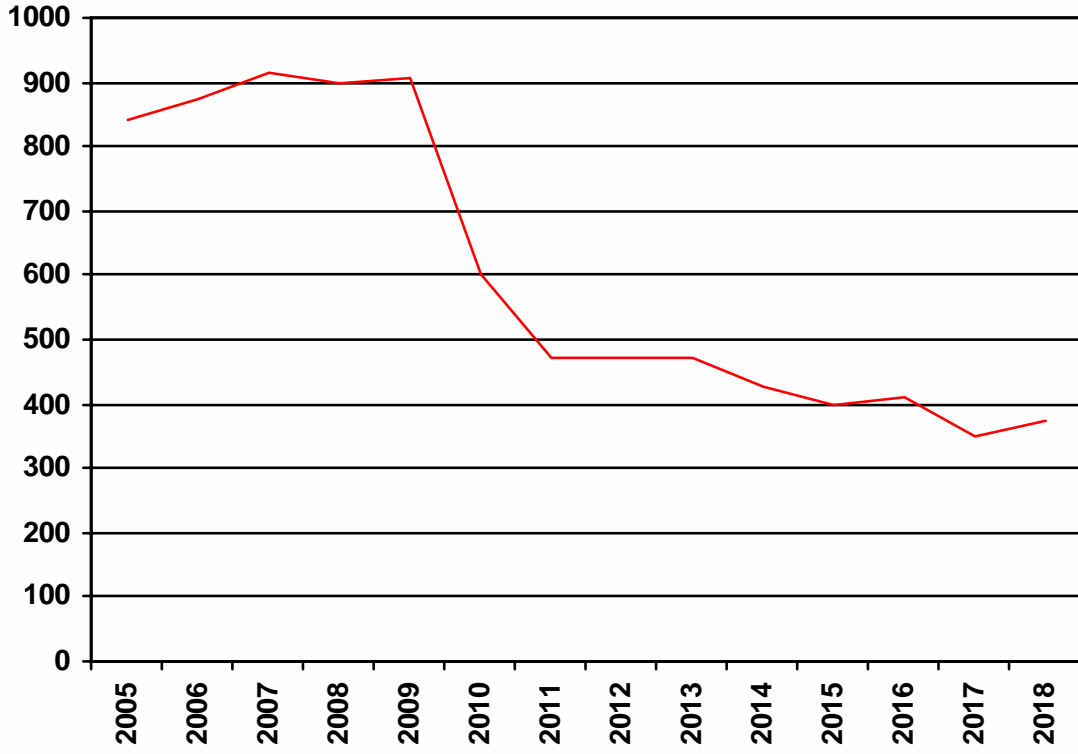
Resulting in...

Significant Power Generation Cost Reduction

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12/31/05 SO₂ Allowance Forward Pricing



**Maximum Upside Predicted over \$900
Trendable Downtrend Not Predicted Until 2009**



Source: Evolution Markets

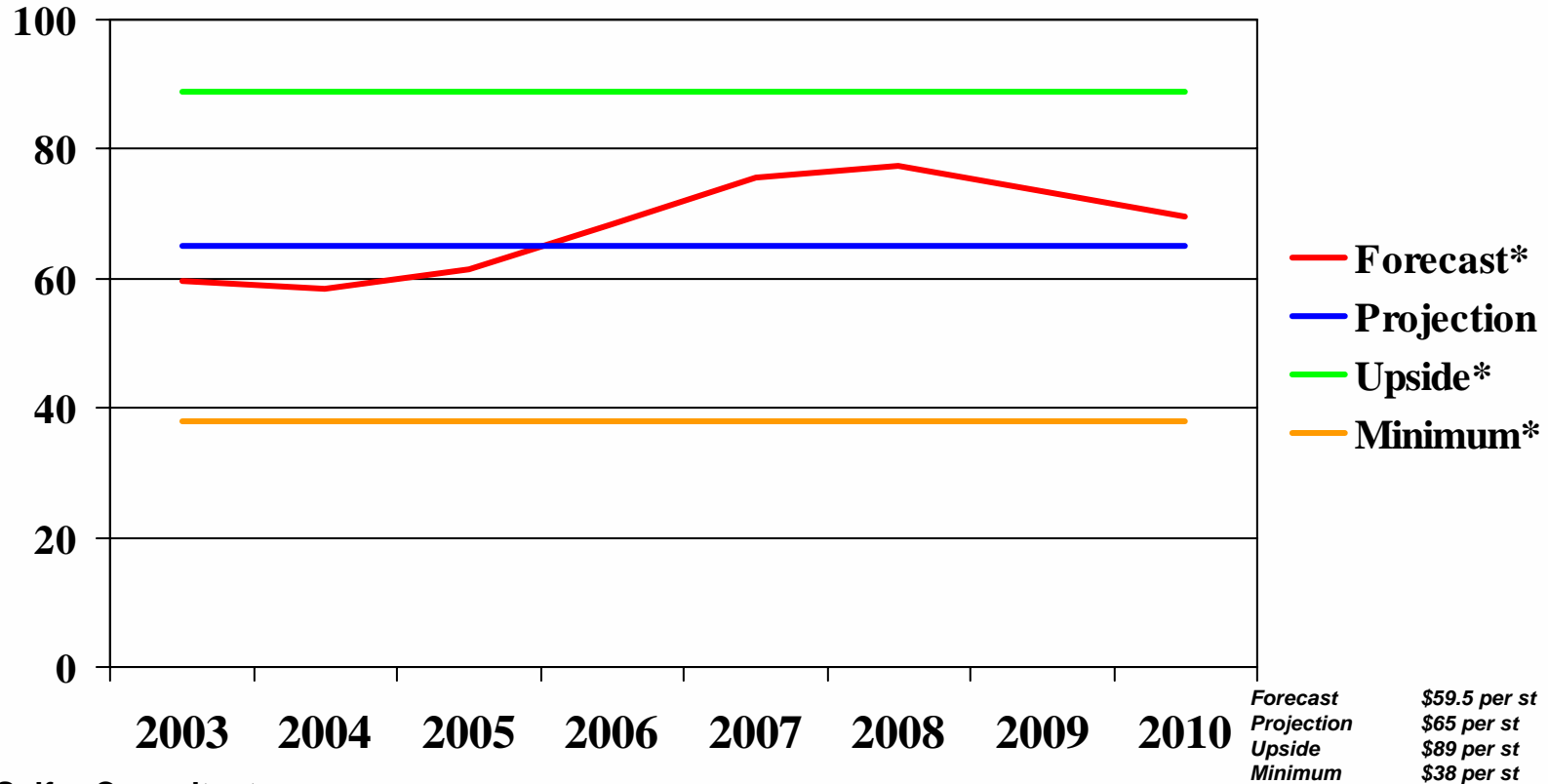


Ten Year Price Scan – AS (\$/T FOB Bulk Prices)

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Great Lakes	133	134	134	119	111	137	130	141	162	211
Southern Plains	110	114	110	93	100	125	113	123	148	178
South Central	115	116	115	97	97	126	114	121	147	181
South East	120	121	124	110	109	128	120	131	156	187
Mid-Corn	126	128	130	114	121	134	127	139	163	202



Forecast / Projection Toll Value, AS Basis



* British Sulfur Consultants

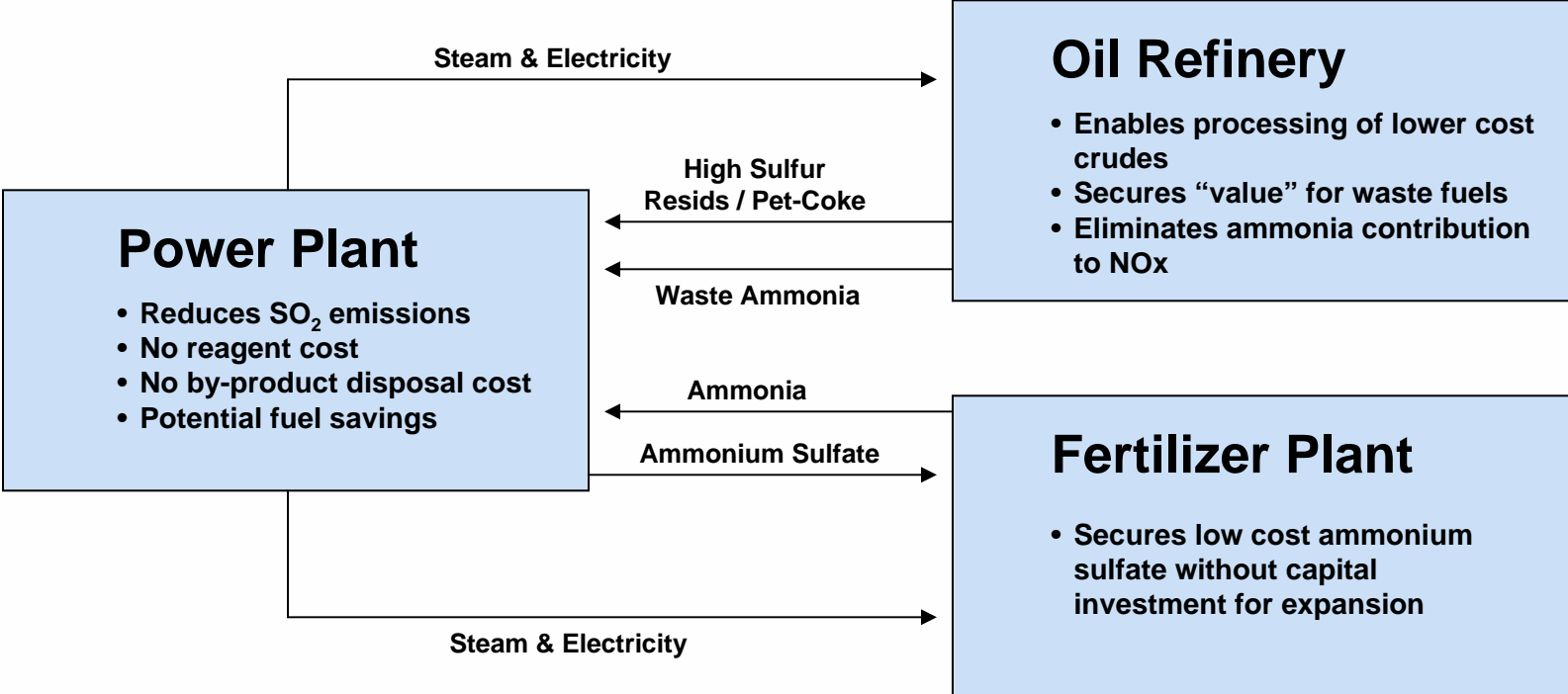
Current Market Influences Not Reflected in Toll Forecast:

- Honeywell forecasting decreased production of byproduct AS as result of weakness in caprolactum market
- Ammonium nitrate imports restricted due to volatile nature reducing a source of "N"
- Sulfur deficiency in soils will continue to be aggravated by FGD installation





Energy & Environment Infrastructure Integration



MLX Technology Can Provide Benefits to China's Industrial Infrastructure Base





Economic Factors Utilized for Evaluation

Factors Common to Limestone and Ammonia:

<i>Factor</i>	<i>Minimum</i>	<i>Probable</i>	<i>Upside</i>
<i>Unit Capacity Factor</i>	<i>80%</i>	<i>83%</i>	<i>83%</i>
<i>Total boiler heat input, mmBTU/yr</i>	<i>37,843,200</i>	<i>39,262,320</i>	<i>39,262,320</i>
<i>Fuel heating values, BTU/lb:</i>			
<i>Low sulfur coal</i>	<i>12,768</i>	<i>12,768</i>	<i>12,768</i>
<i>Mid/High sulfur coal</i>	<i>12,329</i>	<i>12,329</i>	<i>12,329</i>
<i>Pet coke</i>	<i>14,000</i>	<i>14,000</i>	<i>14,000</i>
<i>Fuel Costs, \$/mmBTU:</i>			
<i>Low sulfur coal</i>	<i>\$ 1.42</i>	<i>\$ 1.42</i>	<i>\$ 1.42</i>
<i>Mid/High sulfur coal</i>	<i>\$ 1.35</i>	<i>\$ 1.32</i>	<i>\$ 1.32</i>
<i>Pet coke</i>	<i>\$ 0.90</i>	<i>\$ 0.85</i>	<i>\$ 0.85</i>
<i>Uncontrolled SO₂ emissions, tpy</i>	<i>27,742</i>	<i>28,783</i>	<i>28,743</i>
<i>SO₂ Allowance Value, \$/t</i>	<i>\$ 700</i>	<i>\$ 800</i>	<i>\$ 900</i>



Economic Factors Utilized for Evaluation

Factors Specific to Limestone and Ammonia:

<i>Factor</i>	<i>Minimum</i>	<i>Probable</i>	<i>Upside</i>
<i>SO₂ removal efficiency, % (limestone/ammonia)</i>	<i>95% / 96%</i>	<i>95% / 97%</i>	<i>95% / 98%</i>
<i>Limestone cost, \$/t</i>	<i>\$ 14</i>	<i>\$ 12</i>	<i>\$10</i>
<i>Gypsum sell price, \$/t</i>	<i>\$ 3</i>	<i>\$ 4</i>	<i>\$ 5</i>
<i>Ammonia cost, \$/t</i>	<i>\$ 420</i>	<i>\$ 380</i>	<i>\$ 320</i>
<i>Ammonium sulfate sell price, \$/t</i>	<i>\$ 160</i>	<i>\$ 180</i>	<i>\$ 190</i>



Preliminary Evaluation Results

Medium Sulfur Case: 2.5% Sulfur Blend Low S Coal & Pet Coke:

<i>Evaluative Factor</i>	<i>Minimum</i>	<i>Probable</i>	<i>Upside</i>
<i>Payback Period on Incremental Capital for ammonia technology, years</i>	9.5	4.0	2.6



Preliminary Evaluation Results

High Sulfur Case: 3.8% Sulfur Blend High S Coal & Pet Coke:

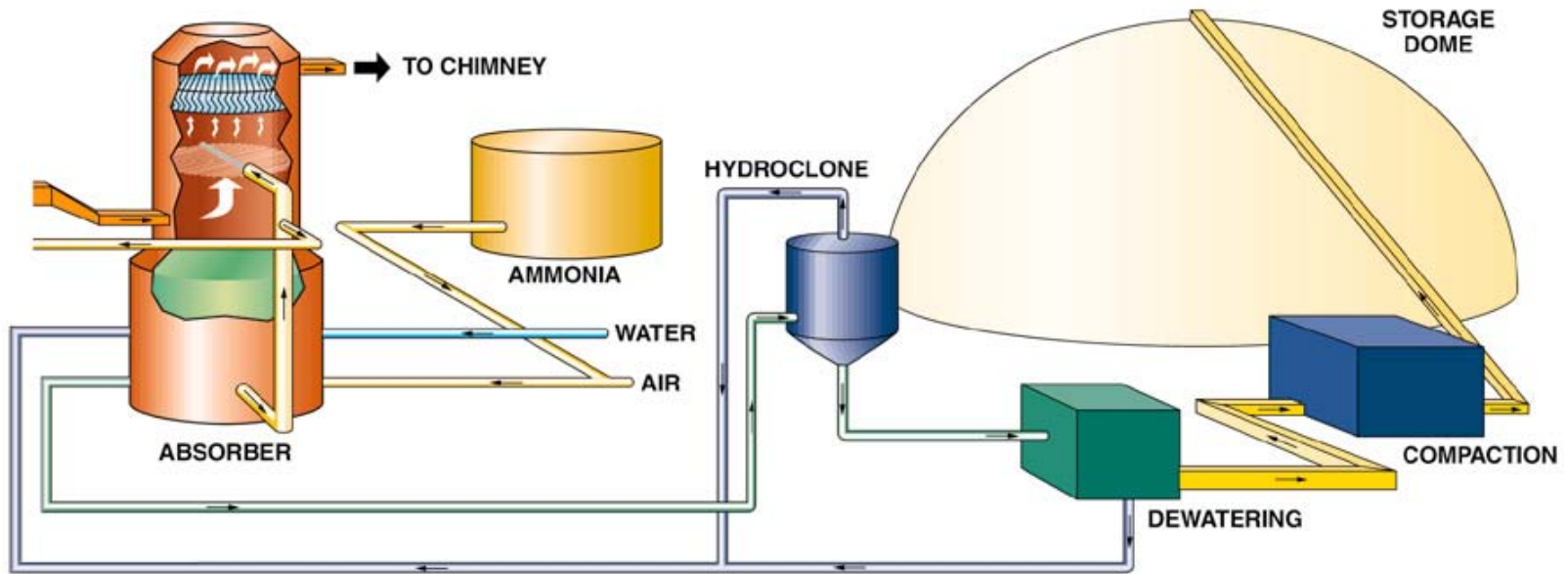
<i>Evaluative Factor</i>	<i>Minimum</i>	<i>Probable</i>	<i>Upside</i>
<i>Payback Period on Incremental Capital for ammonia technology, years</i>	5.2	2.6	1.8



- ◆ In Summary, the best opportunities to apply MET's AS technology will be found at power plants that match the following profile:
 - High fuel cost
 - Low load factor
 - Proximity of navigable water, or good rail access for PetCoke, Ammonia and ammonium sulfate transportation
 - Preferably in a location with high ammonium sulfate prices



The Marsulex Ammonium Sulfate Process



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