The Improved Hard Process: Current Status and Next Steps
A patented, transformational technology for phosphoric acid production
• 10,000 ton per year facility built in 2013 near Fort Meade
• Key aspects of technology have been demonstrated

IHP provides advantages across the value chain
• Uses low grade, higher impurity rock that expands reserves
• Lower Capex and Opex per ton of product than existing technology
• Produces higher quality super phosphoric acid
• IHP co-product is a useful aggregate (no phosphogypsum)
IHP as Originally Envisioned
Key Technological Innovations that Make IHP Commercial

• Chemistry control to avoid melting of feed stock in kiln and to lower reduction reaction temperatures

• Heat treatment process that produces a hardened, low dust and higher purity agglomerate to the reduction kiln

• Grind size control to improve reaction kinetics and heat treatment properties

• A rotary kiln designed to achieve high phosphorus yields with a high temperature reduction zone and a controlled oxidation zone

• Kiln heat capture opportunities
Key Elements of Initial Flowsheet Demonstrated

- Control of feedstock melting at high temperatures
- Release of phosphorous gas in reduction zone
- Oxidation to phosphate \((\text{P}_4\text{O}_{10})\) within ported kiln
- Demonstrated ability to absorb \(\text{P}_4\text{O}_{10}\)
- Temperature control in reduction kiln via controlled oxidation
Single Kiln Operational Setback and Solution

- Reduced kiln operating times due to excess dust formation
- Patented process to pre-treat agglomerates
  - Achieving ~10-20x strength improvement
  - Drives off other impurities to improve acid quality
  - Demonstrated multiple times at 10,000 TPY scale kiln

Other Lab Developments

- Refinement of grind sizes to improve
  - Low temperature yields
  - Pre treatment strength
- Understanding of fluorine evolution dependencies during reduction
- Successfully tested 5 ore sources from different geographies
IHP Flowsheet with Pre-Treatment Kiln
Heat Treatment to Reduce Dust Potential in Kiln

- ~10-20x hardening of agglomerates
- Occurs at temperatures below reduction
- Finer grind size improves strength
- Impurities are removed during the heat treatment
- Achieved at demo plant scale multiple times
Indurated agglomerates are strongest directly after induration and at hottest point.
No signs of sticky or molten state.
**Demo Plant Data: Induration Impurity Removal**

<table>
<thead>
<tr>
<th></th>
<th>Pre-Induration*</th>
<th>Post-Induration*</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>7,053</td>
<td>2,800</td>
<td>60</td>
</tr>
<tr>
<td>Arsenic</td>
<td>6.1</td>
<td>2.3</td>
<td>62</td>
</tr>
<tr>
<td>Cadmium</td>
<td>2.2</td>
<td>0.2</td>
<td>91</td>
</tr>
<tr>
<td>Lead</td>
<td>6.0</td>
<td>0.2</td>
<td>97</td>
</tr>
<tr>
<td>Chloride</td>
<td>7,192</td>
<td>345</td>
<td>95</td>
</tr>
</tbody>
</table>

** These relative % reductions have been repeated multiple times with different ore sources.
Summary

- JDC has demonstrated the key IHP technical elements
  - Silica and melt control
  - Carbo-thermal reduction of phosphorous
  - Downstream oxidation in same vessel
  - Ability to absorb phosphorous gases in acid plant

- JDC has patented new technology to solve key issue
  - Addition of pre-treating kiln to harden agglomerates 10 fold
  - Further impurity removal in pre-treating kiln to improve acid quality
  - Demonstrated on semi-continuous basis with large 93 foot kiln
  - Additional heat capture opportunity with two kiln operation
  - Grind size impacts to yield and pre-treatment
Path Forward

- Achieving financing to build scaled down pilot plant
  - Continuous operation with good operating times
  - Two kiln flowsheet with appropriate burners and porting systems
  - Grinding and feed stock mixing flexibility
  - Full Acid plant with HF removal circuit
  - Indirect cooler to preserve co-product “J-Rox” stream
  - Heat capture system on first kiln
  - Sized with ability to scale up
  - Ability to test other ore sources

- Design larger scale IHP plants based on pilot plant data