Agenda

- Air Products Slurry Gasification Technology
- Slurry Gasification Design Options
- Petcoke & Coal Experience
- Licensed Plants – a Summary
- Air Products Syngas Solutions Offering
Air Products Slurry Gasification Technology

• AP Slurry Gasification is based on Entrained bed, Slurry feed, Slagging mode, Refractory walled reactor with direct water quench and heat recovery options

• Gasification technology leader since 1948 with 100+ commercial plants in operation with 80+ licenses worldwide
  ➢ First Oil Gasification plant in 1959
  ➢ First Coal Gasification plant in 1978
  ➢ First Petcoke Gasification plant in 1984

Reliable and Proven Gasification Technology with Worldwide Experience
Solids Feed - Two Configurations

**Quench**

- Hot syngas immediately quenched by direct water contact
- Syngas is warm and saturated with water... ideal for sour CO shift
- Pressures up to 87 bar
- Proven gasifier sizes up to nominal 900 ft\(^3\); 1800 ft\(^3\) under design
- Typical applications: chemicals, hydrogen, refinery polygen
- Lower capital cost than RSC

**Radiant Syngas Cooler**

- Hot syngas first cooled by radiant cooling before quenching
- Generates high pressure steam to up to 138 bar
- Pressures up to 87 bar
- Proven up to nominal 1800 ft\(^3\)
- Typical applications: power generation, chemicals, hydrogen, refinery polygen
- Better efficiency than quench due to heat recovery
Air Products Slurry Gasification Experience - Petcoke

• 1960s – Early R&D, Pilot testing and Semi commercial test began

• 1980s – First commercial Petcoke application at Eastman/Ube

• Further Industrial applications in Coffeyville Urea/ Refinery H₂

• 100+ years commercial gasification operating experience on petroleum coke and coke/coal blends

• Have plant sending 100% of CO₂ to EOR, so no emissions in normal operation

• Low cost gasifier sparing can provide consistent syngas availability over 98-99%
China Plant Startup History

- Team has started up over 50 Gasification plants in China since 1993
- Improved Time to maturity and quicker commercial production in different product plants
- Simpler gasification process design facilitated highest localization of process equipment fabrication
- Best in class Technical services and Startup support while enabling seamless coordination among DEC, EPC & Vendors
- Growing Experienced Operator base leveraging industry lessons learnt and building successful gasification plants.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Contract to Mechanical Completion</th>
<th>Gasifier Configuration</th>
<th>1st Year Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>31 months</td>
<td>2+1 900 ft³ @ 65 bar</td>
<td>91.9%</td>
</tr>
<tr>
<td>B</td>
<td>18 months</td>
<td>2+0 450 ft³ @ 65 bar</td>
<td>92.5%</td>
</tr>
<tr>
<td>C</td>
<td>31 months</td>
<td>2+1 900 ft³ @ 65 bar</td>
<td>91.5%</td>
</tr>
<tr>
<td>D</td>
<td>35 months</td>
<td>2+1 900 ft³ @ 65 bar</td>
<td>91.4%</td>
</tr>
<tr>
<td>E</td>
<td>32 months</td>
<td>5+2 900 ft³ @ 65 bar</td>
<td>95.0%</td>
</tr>
<tr>
<td>F</td>
<td>24 months</td>
<td>2+1 900 ft³ @ 50 bar</td>
<td>92.0%</td>
</tr>
<tr>
<td>G</td>
<td>32 months</td>
<td>2+1 900 ft³ @ 65 bar</td>
<td>91.5%</td>
</tr>
<tr>
<td>H</td>
<td>43 months</td>
<td>2+1 900 ft³ @ 65 bar</td>
<td>92.1%</td>
</tr>
<tr>
<td>I</td>
<td>18 months</td>
<td>4+2 900 ft³ @ 87 bar</td>
<td>91.8%</td>
</tr>
<tr>
<td>J</td>
<td>36 months</td>
<td>2+1 900 ft³ @ 40 bar</td>
<td>92.0%</td>
</tr>
<tr>
<td>K</td>
<td>40 months</td>
<td>2+1 450 ft³ @ 65 bar</td>
<td>91.8%</td>
</tr>
<tr>
<td>L</td>
<td>18 months</td>
<td>2+1 450 ft³ @ 45 bar</td>
<td>93.1%</td>
</tr>
<tr>
<td>M</td>
<td>45 months</td>
<td>10+4 900 ft³ @ 65 bar</td>
<td>91.3%</td>
</tr>
<tr>
<td>N</td>
<td>39 months</td>
<td>5+2 900 ft³ @ 65 bar</td>
<td>90.5%</td>
</tr>
</tbody>
</table>
Coffeyville Resources Nitrogen Fertilizers LLC

- Licensee/Owner: Coffeyville Resources
- Operator: Coffeyville Resources
- Location: Coffeyville, Kansas, USA
- Startup: 2000
- Feedstock: Petroleum Coke
- Design Capacity: 1,300 STPD (per gasifier)
- Operation Pressure: 620 psig (43 bar)
- Gasifier Config: 2 Quench gasifier train
- EPC Contractor: Black & Veatch

On-stream factors for gasification and ammonia production from CVR Annual report

<table>
<thead>
<tr>
<th></th>
<th>Gasification</th>
<th>Ammonia</th>
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<tr>
<td>2015</td>
<td>99.9%</td>
<td>97.7%</td>
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<tr>
<td>2014</td>
<td>98.2%</td>
<td>94.3%</td>
</tr>
<tr>
<td>2013</td>
<td>99.5%</td>
<td>98.9%</td>
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LCVR’s Annual Form 10K 2016 report weblink: Pg 101
http://investors.cvrenergy.com/static-files/c7e04ba5-db2d-4888-be54-e5c1e6415deb
TECO Polk Power Station

- Single 1,800 ft³ gasifier operating at 375 psig, 123 MMSCFD of H₂+CO to power one 7FA GE Gas turbine
- 2,500 ton per day Original designed 100% coal ran 85% coke, 15% coal for last 11 years of operation
- Slag screening & 100% fines recycle
- 250 MW (net) Power to grid
Case Study: ZTHC Zhongtian
Reached/Sustained Capacity Quickly

- 14.7 hrs from start-up until standard MeOH produced
  - 23rd Sep, 2016 first fire of first gasifier
  - 24th Sep, 2016 On spec MeOH production starts

- 65 Days from start to full production of first series of 5op+2sp gasifiers
  - On 28th Nov, 2016 Plant achieve 110% of designed MeOH production

Started : 2016
Gasifiers : 900 cu ft, 10op+4sp
Pressure : 65 bar g
Products : 3.6 MMTPA MeOH

One of the Largest gasification plants in world

World record for slurry gasification scale/speed
Case Study: Pucheng Gasification Project
Savings from High Pressure

- High pressure configuration eliminated one gasifier train and associated equipment
- 60% MeOH Synthesis Compressor energy saving,
- 50% AGR energy saving
- Less fouling in HP grey water system

Started: 2014  
Gasifiers: 900 cuft, 4op + 2sp  
Pressure: 86 bar g  
Products: 1.8MMPTA MeOH, MTO

<table>
<thead>
<tr>
<th>Single train</th>
<th>Unit</th>
<th>NOC</th>
<th>Operation</th>
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<tbody>
<tr>
<td>Pressure</td>
<td>Bar g</td>
<td>86</td>
<td>81</td>
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<tr>
<td>Syngas output</td>
<td>kNm³/hr</td>
<td>139</td>
<td>144.3</td>
</tr>
<tr>
<td>(CO+H₂)</td>
<td>%</td>
<td>78</td>
<td>80 - 83</td>
</tr>
</tbody>
</table>
Air Products offer SOG and Licensing

SOG (Sale of Gas)

✓ Air Products offers complete turnkey gasification complex where AP builds, finances, owns and operate the syngas production facility

✓ Offers a best cost efficiency enabling customers to focus valuable capital, management and personnel on their primary value added products

Licensing or SOE (Sale of Equipment)

✓ This option offer legacy licensing business model, process design package and sale of proprietary equipment

✓ Also offers, technical services, commissioning, start up and performance testing to customer
Thank you
tell me more

Hidayathullah Mohammad
Senior Engineer – Gasification Technology
MOHAMMH1@airproducts.com

http://www.airproducts.com/Microsites/syngassolutions.aspx
## Slurry Licensed Petcoke, Coal blend reference list

<table>
<thead>
<tr>
<th>Location (Country)</th>
<th>Startup</th>
<th>Primary Feedstock</th>
<th>Size, cu.ft</th>
<th># of Gasifiers (Op+Sp)</th>
<th>Operating Pressure, barG</th>
<th>H$_2$+CO, MMSCFD (kNm$^3$/hr)</th>
<th>End Product</th>
<th>Mode</th>
<th>Project Status</th>
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</thead>
<tbody>
<tr>
<td>Japan 1984</td>
<td>Petcoke</td>
<td>450</td>
<td>3 + 0</td>
<td>38</td>
<td>78.9 (88.1)</td>
<td>Ammonia Quench</td>
<td>Operating</td>
<td></td>
<td></td>
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<tr>
<td>USA 1996</td>
<td>Coal/Petcoke</td>
<td>1800</td>
<td>1 + 0</td>
<td>26.2</td>
<td>123 (137.3)</td>
<td>Power RSC+CS</td>
<td>Operating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA 2000</td>
<td>Petcoke</td>
<td>900</td>
<td>1 + 1</td>
<td>43</td>
<td>86 (96)</td>
<td>Ammonia Quench</td>
<td>Operating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA 2001</td>
<td>Petcoke</td>
<td>900</td>
<td>2 + 0</td>
<td>66.9</td>
<td>138.9 (155)</td>
<td>Steam, Power Quench</td>
<td>Shutdown</td>
<td></td>
<td></td>
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<tr>
<td>China 2005</td>
<td>Coal/Petcoke</td>
<td>900</td>
<td>2 + 1</td>
<td>40</td>
<td>122.7 (137)</td>
<td>Ammonia/Hydrogen Quench</td>
<td>Operating</td>
<td></td>
<td></td>
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<tr>
<td>China 2006</td>
<td>Coal/Petcoke</td>
<td>900</td>
<td>1 + 1</td>
<td>85</td>
<td>78.4 (87.5)</td>
<td>Ammonia/Urea Quench</td>
<td>Operating</td>
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<td>China 2008</td>
<td>Coal/Petcoke</td>
<td>450</td>
<td>2 + 1</td>
<td>58</td>
<td>89.5 (99.9)</td>
<td>Oxochemicals Quench</td>
<td>Operating</td>
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<td>China 2014</td>
<td>Coal/Petcoke</td>
<td>900</td>
<td>2 + 1</td>
<td>65</td>
<td>190.8 (213)</td>
<td>Hydrogen Quench</td>
<td>Operating</td>
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<td>China 2020</td>
<td>Petcoke</td>
<td>900</td>
<td>4 + 2</td>
<td>65</td>
<td>403.1 (450)</td>
<td>Hydrogen Quench</td>
<td>Construction</td>
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<td></td>
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<tr>
<td>USA 2023</td>
<td>Petcoke</td>
<td>1800</td>
<td>3 + 1</td>
<td>67.2</td>
<td>441 (492)</td>
<td>MeOH/Hydrogen Quench</td>
<td>Design/EPC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

50 Coal feed gasification plants are licensed and 35 plants are currently operating and seven in various EPC stages.