Integration of KBR’s TRIG & Ammonia Technologies – Low Rank Coal to Ammonia

Manoj Nagvekar
Structure – Streamlined / Focused

KBR

Technology & Consulting

Engineering & Construction

Government Services
Technology & Consulting Business

KBR Technology & Consulting

- KBR Technology
- Granherne
  A KBR Company
- GVA
  A KBR Company
- Energo
  A KBR Company
Portfolio Offerings
Downstream & Syngas Technologies

Veba Combi Cracking (VCC™)
• Convert Heavy Hydrocarbon Streams to Fuels
• Produces On-Spec Fuels with 95%+ Once-Through Conversion

KBR Catalytic Olefins Technology (K-COT™)
• Highest Propylene-to-Ethylene Ratio
• Flexibility to Process High- or Low-Quality Feedstocks

Fertilizer Technology
• Global Market Leader in Ammonia Technology
• Over 200 Plants Globally
• Energy Efficient Technology

Transport Integrated Gasification (TRIG™)
• Only Gasification Technology Designed to Process
  High-Moisture, High-Ash Coals
• Chemicals, Synthetic Natural Gas, or Power Applications
KBR Technology Business Segments

- Refining
- Olefins
- Chemicals
- Ammonia and Syngas
- Coal Monetization
- Automation and Process Technologies
- Proprietary Equipment

Scope
- Licensed Technology
- Proprietary Equipment and Catalysts
- Basic Engineering and Design
- Support for Detailed Engineering
- Commissioning and Start-Up Services
- Plant Operations Management Systems
- Operator Training Simulators
- Technical Services and Studies
- Revamping and Retrofits

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Outline

- KBR TRIG™ Coal Gasification Technology
  - Low Rank Coal – A Low Cost Feedstock Opportunity
  - KBR’s Technology Solution for Low Rank Coals
  - KBR’s Coal to Ammonia Process
  - Coal to Ammonia Economics
  - TRIG Projects
Feedstock for Ammonia

GLOBAL AMMONIA CAPACITY
205.2 Million tonnes, 2012

Source: International Fertilizer Association 2012
Syngas for Ammonia

- Ammonia is very price sensitive
- TRIG uses inexpensive feedstock for syngas production
- KBR Coal to Ammonia process is robust and energy-efficient
- Low CAPEX and OPEX due to KBR Integration
TRIG developed by KBR, Southern Company with support from U.S. DOE

KBR-Southern Alliance:
- Collaborative blending of skills and strengths of each company
- Technology available for **Industrial and Power** applications of TRIG using low-rank coals
- KBR leads marketing and licensing activities

TRIG: Advanced gasification technology solution ready to unlock the potential of low rank coals for you!
Proven Technology Platform for Low Rank Coals

TRIG Leverages Long History of Fluid Catalytic Cracking (FCC) Expertise

- **Late 1930s**
  - First Commercial FCC Unit for Exxon

- **1942**
  - OrthoFlow™ A Design

- **1951**
  - OrthoFlow™ C Design

- **Early 1960s**
  - Resid FCCs

- **1976**
  - OrthoFlow™ F Design

- **1980s**
  - Design Based on FCC Technology

- **1990**
  - Pilot Plant Tech Center

- **1996**
  - Grand Forks, ND 2,600 Hours Test Run

- **1996**
  - PSDF at Wilsonville, AL. >14,600 hrs in gasification >2,200 hrs on Mississippi Lignite thru Dec ‘09

- **2014**
  - TRIG In Kemper County, MS, USA, DongGuan, China & Inner Mongolia, China
TRIG: The beginning of opportunities

TRIG specifically developed for low rank coals!
KBR Proprietary Coal to Ammonia Process

- Syngas Generation using Transport Gasifier Technology (TRIG)
- Syngas Purification
- KBR Ammonia Synthesis Technology
Syngas Generation via TRIG

AIR → ASU → KBR TRANSPORT GASIFIER (TRIG) → SYNGAS COOLER → PARTICULATE CONTROL DEVICE

STEAM → O₂ → ASU

N₂ → HP STEAM

COAL FEED → COAL PREPARATION & MILLING

COARSE ASH → BFW

FINE ASH → TO SYNGAS TREATMENT

98.0 mol%
Syngas Cooler

- AIR
- STEAM
- N₂
- O₂
- HP STEAM
- ~ 980 °C
- ~ 370 °C
- SYNGAS COOLER
- COAL PREPARATION & MILLING
- COAL FEED
- PARTICULATE CONTROL DEVICE
- FINE ASH
- BFW
- COARSE ASH
- TO SYNGAS TREATMENT
Syngas Purification

CO \sim 2.0 - 4.0 \text{ mol}\% 
COS \sim 1 - 10 \text{ ppmv}

CO + H_2O \rightleftharpoons CO_2 + H_2

COS + H_2O \rightleftharpoons CO_2 + H_2S

SOUR GAS SHIFT (TWO STAGE)

WASTE HEAT RECOVERY

MERCURY REMOVAL

ACID GAS REMOVAL UNIT

SYNGAS SATURATOR

SYNGAS FROM PCD

SYNGAS TO SATURATOR

STEAM

CONDENSATE

BLOWDOWN

H_2 \sim 0.2

S/G \sim 0.2

S/G \sim 1.0

H_2S \sim 0

CO_2 \sim 2.0 - 5.0 \text{ mol}\%

H_2 > 99.5 \text{ mol}\%

H_2S

CO_2

H_2

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Advantages of KBR Coal to Ammonia Process

Flexibility of Feedstock
- Suitable for most abundant, lowest cost coals
- Suitable for high ash coals

Increased Gasifier Reliability
- Lower operating temperature
- No internals
- 60+ years of successful FCC experience
- No Spare Required

Lower Capital Cost
- Compact gasifier design
- Less expensive materials of construction
- Single TRIG for up to 2000 MTPD NH₃
- No slag handling equipment
- KBR Synloop – lower pressure drop, fewer equipment items
Advantages of KBR Coal to Ammonia Process

Higher Energy Efficiency
- High carbon conversion
  > 99% typical
- High grade process heat recovery
- Medium-low grade process heat recovery

High Quality Syngas
- Particulate free
- Negligible tars and oils

Environmentally Friendly
- No black water
- Low net water requirement
- Efficient CO₂ capture
Economic Considerations

Lower OPEX
- Lower specific energy consumption
- Suitable for lowest cost, most abundant coals
- TRIG has high reliability

Lower CAPEX
- Single TRIG up to 2000 MTPD NH₃
- KBR Synloop with fewer equipment
- Expected cost lower than competing designs
Coal to Ammonia - Economics

- **Basis:** 2000 MTPD Ammonia
- **Coal Feed:** ~4200 MTPD (~ 4100 kcal/kg HHV arb)
- **Coal Price:** $20/MT
- **Estimated Cost of Ammonia Production:** $295/MT

Current Price is approximately $500/MT
Coal to Ammonia - Impact on Project Economics

Capital Structure: 60% Debt / 40% Equity
Cost Basis: China
Tax rate: 25%
Cost of Financing: 8%

Variation in Cost of Ammonia Production, $/MT

- Capex +/- 25%
- Coal Price +/- 50%
- Availability +/- 5%
- Corporate Tax Rate +/- 10%
KBR Gasification Projects – Global Footprint

- **UND Pilot**: 3 MTPD – 1996
- **PSDF Demo**: 50 MTPD
- **SKI Pilot**: 3 MTPD
- **Yanchang Demo**: 100 MTPD – 2011
- **DongGuan IGCC**: 1600 MTPD
- **Berun TRIG**: 1000 MTPD
- **Kemper TRIG IGCC**: 582 MW

Projects: UND Pilot, PSDF Demo, SKI Pilot, Yanchang Demo, DongGuan IGCC, Berun TRIG, Kemper TRIG IGCC
TRIG 600 MW Lignite IGCC Project: Mississippi, USA

Kemper County IGCC Project

- Plant owned and operated by Mississippi Power Company (MPC) and the Southeast Mississippi Electric Power Authority (SMEPA)

- Lignite-fueled 2-on-1 Integrated Gasification Combined Cycle (IGCC) facility using air-blown TRIG gasification

- 65% CO₂ capture (EOR use)

- Commissioning in progress

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Kemper County TRIG IGCC Overview

- **2x1 Integrated Gasification Combined Cycle (IGCC)**
  - 2 Transport Gasifiers
  - 2 Siemens SGT6 - 5000F CTs
  - 1 Toshiba Steam Turbine
  - 582 MW peak and 524 MW on syngas
  - Heat Rate: **12,810 kJ/kWh**
  - UOP’s Selexol Process for H2S and CO2 removal
  - Haldor Topsøe’s Wet Sulfuric Acid for H2SO4 production
  - 65% CO2 capture (~360 kg/MWh emission rate)
  - Mine Mouth Lignite

- **Owner & Operator: Mississippi Power**

- **By-Products (metric tonnes per year)**
  - 2,720,000 Carbon dioxide used for EOR
  - 122,000 Sulfuric acid
  - 18,000 Ammonia

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**Kemper Lignite Composition**

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Range</th>
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<tbody>
<tr>
<td>LHV kcal/kg</td>
<td>2572</td>
<td>2317 – 2854</td>
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<tr>
<td>Moisture %</td>
<td>45.5</td>
<td>42 – 50</td>
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<tr>
<td>Ash %</td>
<td>12</td>
<td>8.6 – 17</td>
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<tr>
<td>Sulfur %</td>
<td>1</td>
<td>.35 – 1.7</td>
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# Key Startup Milestones Completed

<table>
<thead>
<tr>
<th>Key Milestones</th>
<th>Completion Date</th>
</tr>
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<tbody>
<tr>
<td>✓ Admin/Control Building - DCS Control System</td>
<td>21-Sep-12</td>
</tr>
<tr>
<td>✓ Functional</td>
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</tr>
<tr>
<td>✓ Start Filling Treated Effluent Reservoir</td>
<td>15-Oct-12</td>
</tr>
<tr>
<td>✓ Station Service Energized</td>
<td>8-Nov-12</td>
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<tr>
<td>✓ Water Treatment Plant Commissioning Completion</td>
<td>30-Mar-13</td>
</tr>
<tr>
<td>✓ Cooling Tower Completion</td>
<td>10-Apr-13</td>
</tr>
<tr>
<td>✓ Fire Auxiliary Boiler</td>
<td>5-Aug-13</td>
</tr>
<tr>
<td>✓ First Fire Combustion Turbine – A</td>
<td>28-Aug-13</td>
</tr>
<tr>
<td>✓ First Fire Combustion Turbine – B</td>
<td>4-Sep-13</td>
</tr>
<tr>
<td>✓ Steam Turbine – Sync To Grid</td>
<td>5-Oct-13</td>
</tr>
<tr>
<td>✓ Gasifier First Fire – A and B</td>
<td>5-Mar-15</td>
</tr>
<tr>
<td>• Reliable Syngas To Combustion Turbine A</td>
<td>TBD</td>
</tr>
<tr>
<td>• Reliable Syngas To Combustion Turbine B</td>
<td>TBD</td>
</tr>
</tbody>
</table>

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