Kemper County IGCC – Overview and Operational Summary

2017 Syngas Technologies Conference

Landon Lunsford
October 18, 2017
Agenda

• Unique features and major process components
• Operational summary and statistics
• Remaining technical challenges
• Conclusions
• Next steps
Safety

• Project groundbreaking: June 2010
• Construction begins: First half of 2011
• Combined-cycle in service: August 2014
• First coal feed to gasifier: July 2016
• Operations suspended: June 28, 2017
• Total project man-hours: 41+ MM
• Recordable Incident Rate (RIR) = 0.42
• Total plant man-hours: ~2.5 MM
• RIR = 0.16
Kemper County IGCC Overview

- Mine-mouth lignite
- 2x1 IGCC
  - Two Transport Gasifiers (TRIG™)
  - Two Siemens SGT6 - 5000F CTs
  - 65+% carbon capture (~550 lb\(_{\text{CO}_2}/\text{Mwh}_{\text{gross}}\))
  - ~60 miles of CO\(_2\) pipeline
  - 582 MW peak and 526 MW on syngas
  - Heat rate 12,150 Btu/kWh\(_{\text{NET}}\)
- Co-products (TPY)
  - ~3,800,000 - CO\(_2\) used for EOR
  - ~150,000 - sulfuric acid
  - ~19,000 – ammonia

### Kemper Lignite Composition

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Content</td>
<td>btu/lb</td>
<td>5,290</td>
<td>4,765</td>
</tr>
<tr>
<td>Moisture</td>
<td>%</td>
<td>45.5</td>
<td>42</td>
</tr>
<tr>
<td>Ash</td>
<td>%</td>
<td>12.0</td>
<td>8.6</td>
</tr>
<tr>
<td>Sulfur</td>
<td>%</td>
<td>1.0</td>
<td>0.35</td>
</tr>
</tbody>
</table>

![Plant Site](image)
Kemper Block Flow Diagram

GASIFIER ISLAND
- LIGNITE
- Lignite Drying and Milling
- PDAC
- CCAD
  - Coarse Ash Cooling and Depressurization
- AIR
- GASIFIER
- High-Pressure Coal Feed
- High-Temp Syngas Cooling
- SYNGAS
- Particulate Collection
- Water-Gas Shift
- CO+H2O→CO2+H2
- Low-Temp Syngas Cooling and Ammonia Removal
- Sour Water and Ammonia Recovery
- Mercury Removal
- SULFURIC ACID
- WSA Process
- ACID GAS
- CO2
- CO2 and Sulfur Removal
- ANHYDROUS AMMONIA
- Sour Water and Ammonia Recovery

COMBINED-CYCLE
- Condenser
- Steam Turbine
- HP STEAM
- Heat Recovery Steam Generator
- Gas Turbine
- SWEET SYNGAS
- TO STACK

1 of 2 Trains Depicted
Operational Summary

• Achieved fully integrated operation of entire IGCC
  • Both CTs produced power with hydrogen rich syngas
  • Steam turbine produced power with superheated steam from the syngas coolers
  • On spec production of CO$_2$, anhydrous ammonia, sulfuric acid
• First-of-a-kind commercial TRIG™ gasification system
  • Gasifier operation highly flexible over a wide range of pressures, temperatures, and coal feed rates.
  • 90% gasifier availability
• Overall availability following expected availability ramp
• Kemper operation suspended primarily due to significant decrease in price and forecast for natural gas
  • Natural gas prices and forecast decreased 60-70% since 2010 project approval
Coal IGCC Plant Syngas Production Availabilities

Source: Gasification Users Association (GUA): Technology Status - December 2016
TRIG Advantages

- No internal burners / fuel injectors
- Longer expected refractory life
- Dry ash – no molten slag or corrosive / erosive blackwater system
- Higher “first pass” carbon conversion → less tar → less syngas cooler fouling
Key Operating Statistics

- Gasifier operation
  - 224 total days of lignite gasification
  - Achieved 100% gasifier design coal feed capacity
- Syngas cleanup/emissions
  - Met all environmental permit requirements
  - Achieved design 65% CO\textsubscript{2} capture and transport for Enhanced Oil Recovery (EOR)
  - On spec production of CO\textsubscript{2}, ammonia and sulfuric acid
- CT operation on syngas
  - 73% capacity achieved at 170 MW (Siemens initially limited CT capacity on syngas to 70%)
  - Excellent operational flexibility while maintaining combustion stability
    - 100% Natural Gas, 100% Syngas, Co-firing
    - Smooth Startups and Fuel Transitions
    - Fuel following with fixed load, Load following with fuel supply, Fuel pressure following
Remaining Challenges

Inconsistent raw coal quality

- Frequently outside design range for both moisture and particle size
- Modifications in May-June 2017 improved reliability
- Before modifications, sustained 80% gasifier coal feed capacity with three dryers per train
- After modifications, sustained 80% gasifier coal feed capacity with two dryers per train
- Additional changes were being developed and implemented

Kemper Lignite Composition

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Content</td>
<td>btu/lb</td>
<td>5,290</td>
<td>4,765</td>
</tr>
<tr>
<td>Moisture</td>
<td>%</td>
<td>45.5</td>
<td>42</td>
</tr>
<tr>
<td>Ash</td>
<td>%</td>
<td>12.0</td>
<td>8.6</td>
</tr>
<tr>
<td>Sulfur</td>
<td>%</td>
<td>1.0</td>
<td>0.35</td>
</tr>
</tbody>
</table>
Remaining Challenges

Refractory replacement in the gasifier seal leg outlet

• Refractory improperly installed in shop - experienced significant and uncharacteristic spalling during drying, but construction schedule prevented refractory replacement
• Bottom sections replaced in situ during commissioning and worked well thereafter
• Upper section spalled from the seal leg, blocking ash removal and requiring periodic clean-out
• Refractory replacement scheduled for upcoming October 2017 outage would have eliminated significant spalling
Remaining Challenges

Syngas cooler superheater tube leaks

• Numerous leaks developed at tube supports of Coil 5 on multiple superheaters

• Finite element analysis revealed high stress and insufficient tube thickness/design margin at Coil 5 tube support weld connections

• All Coil 5 tubes plugged in each train’s Superheater II
  • Sufficient heat transfer area remaining for full coal feed rates because less tube fouling than expected
  • Inner coils likely under less overall stress than Coil 5 per engineering evaluations

• No additional tube failures, but insufficient operating time to prove conclusively reliable
Remaining Challenges

Excess sour water production from syngas scrubbers
- Damage to scrubber internals and design of chimney trays allowed excessive water bypassing to sour water system
- Sour water system overwhelmed with two gasifier trains at higher coal feed rates
- Internal repairs and chimney tray redesign scheduled for October outage would have resolved this issue
Remaining Challenges

Salt formation in the Sour Water system

- High sour water pH preventing adequate separation of ammonia, CO$_2$ and H$_2$S
- Ammonium bisulfide salts forming in ammonia purification equipment, limiting capacity and reliability at high coal feed rates
- Acid and caustic injection changes in progress to increase pH control and improve separation
Conclusions

• Core TRIG™ technology successfully demonstrated at commercial scale
  • Operated at 100% of coal feed design
  • Produced hydrogen rich syngas and successfully operated CT over wide range of conditions

• Kemper IGCC demonstrated with dual-train operation
  • Additional modifications required to sustain operation of both trains and to achieve the long-term availability ramp

• Historically low natural gas price and forecast was the primary reason for suspension of operations prior to making the identified modifications for sustained dual-train operation
Next Steps

• Evaluate and develop best practices and lessons learned from design, construction, startup and operations of the Kemper IGCC project

• Continue supporting DOE mission to advance clean coal and carbon capture technologies
  • Commissioning and Startup report with lessons learned
  • Final Full Project Technical report with lessons learned
  • TRIG™ reference plant with expected capital and operating costs for next-generation TRIG™ IGCC

• Evaluate alternative uses and potential partners for Kemper gasification, syngas cleanup and carbon capture assets

• Continue supporting development of clean coal technologies to ensure they are ready to serve energy needs where fuel costs and the value of carbon capture and sequestration / utilization make them economically competitive
Questions?