PROJECT DESIGNS FOR IGCC & SNG WITH CO2 SEQUESTRATION

Gasification Technologies Conference

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ConocoPhillips Company
Presentation Outline

- Introduction
- Design Premise
  - Common Processes
  - SNG Configuration
  - IGCC Configuration
- Design Considerations
  - Product and By-Product Specifications
  - Air Separation Unit
  - E-Gas™ Technology Battery Limit
  - CO Shift Area
  - Acid Gas Removal Area
  - CO2 Sequestration
- Summary
- Sweeny IGCC/CCS Project Update
Introduction

- ConocoPhillips is developing projects that convert coal / pet coke to power and/or SNG, with and without CO2 sequestration
- Process schemes and technology selection are impacted by many factors, including:
  - Feedstock
  - Product and by-product specifications
  - Environmental permit limits
  - Site conditions
  - Technology experience, flexibility, reliability
- No common “best” answer for all projects
- Highlight key considerations from recent IGCC and SNG project configurations
Design Premise

- Common Processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site location</td>
<td>U.S. Gulf Coast</td>
</tr>
<tr>
<td>Feedstock</td>
<td>Delayed Petroleum Coke</td>
</tr>
<tr>
<td>Air Separation</td>
<td>“Pumped” cycle, 2X50% trains w/O2 storage</td>
</tr>
<tr>
<td>Gasification</td>
<td>E-Gas™, 2X50% trains w/spare</td>
</tr>
<tr>
<td>CO Shift</td>
<td>2 Stages w/bypass (Level of shift varies with application)</td>
</tr>
<tr>
<td>Acid Gas Removal</td>
<td>Physical solvent, single train optimized</td>
</tr>
<tr>
<td>Sulfur Removal</td>
<td>2 train, Oxy-Claus, 3 stage (1 thermal, 2 catalytic)</td>
</tr>
<tr>
<td>CO2 Compression</td>
<td>Supercritical compression (2200 psig) – Flow varies</td>
</tr>
<tr>
<td>Process Cooling</td>
<td>Wet Cooling Tower</td>
</tr>
</tbody>
</table>

- Additional Processes

<table>
<thead>
<tr>
<th>For SNG Product</th>
<th>1 Train, 4 Stage TREMP™ Methanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>For IGCC</td>
<td>2 on 1 F-Class GTG CC, w/ASU integration</td>
</tr>
</tbody>
</table>
Common Processes

- **ASU**
  - Air → O2 → N2(Vent)
  - Petcoke → Flux, Water, Slag

- **Slurry Prep & Gasification**
  - Petcoke → Flux, Water, Slag

- **Syngas Cooling & CO Shift**
  - Syngas → MU, Water, Waste

- **CO2 Compression**
  - O2 → CO2 Storage/Sales
  - O2 → AGR / SRU

- **STG**
  - Sulfur → Power

- **Syngas**
  - Water

- **Petcoke**
  - Flux, Water, Slag
IGCC Configuration

- **ASU**
  - **Air**
  - **O2**
- **Slurry Prep & Gasification**
  - **Petcoke**
  - **Flux**
  - **Water**
  - **Slag**
- **Syngas Cooling & CO Shift**
  - **MU Water**
  - **Waste Water**
- **CO2 Compression**
  - **O2**
  - **Coal**
- **AGR / SRU**
  - **Syngas**
  - **Sulfur**
- **STG**
  - **Power**
- **Gas Turbine/HRSG Power Block**
  - **Net Power**

- **N2(Power)**
- **N2(Vent)**
- **CO2 Storage/Sales**
## Design Considerations
### - Product Specifications

### SNG Product Specifications – Typical Ranges

<table>
<thead>
<tr>
<th>Spec</th>
<th>Value Range</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHV</td>
<td>1098 - 970</td>
<td>Btu/scf</td>
</tr>
<tr>
<td>Tot S</td>
<td>5 – 1.2</td>
<td>gr/100 scf</td>
</tr>
<tr>
<td>H2S</td>
<td>0.25 - 0.2</td>
<td>gr/100 scf</td>
</tr>
<tr>
<td>CO2</td>
<td>2 - 0.5</td>
<td>vol%</td>
</tr>
<tr>
<td>N2</td>
<td>3 - 1</td>
<td>vol%</td>
</tr>
<tr>
<td>H2O</td>
<td>5 – 0.7</td>
<td>gr/100scf</td>
</tr>
<tr>
<td>H2</td>
<td>1 - 0</td>
<td>vol%</td>
</tr>
<tr>
<td>O2</td>
<td>1 – 0.01</td>
<td>vol%</td>
</tr>
</tbody>
</table>

**Notes**
Additional limits on > C1 paraffin, olefin content, non-hydrocarbons, combined inerts may exist

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Specifications are met with process optimization and syngas cleanup
Design Considerations - By-product Specifications

**CO₂ By-product requirements – Typical Ranges**

- Example Pipeline specifications

<table>
<thead>
<tr>
<th>Spec</th>
<th>Value Range</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>95 - 97</td>
<td>vol%</td>
</tr>
<tr>
<td>H₂</td>
<td>1 - 4</td>
<td>vol%</td>
</tr>
<tr>
<td>CH₄</td>
<td>1 - 4</td>
<td>vol%</td>
</tr>
<tr>
<td>N₂</td>
<td>0.5 - 4</td>
<td>vol%</td>
</tr>
<tr>
<td>H₂O</td>
<td>250 - 500</td>
<td>ppmw</td>
</tr>
<tr>
<td>CO</td>
<td>1000 – 5000</td>
<td>ppmw</td>
</tr>
<tr>
<td>O₂</td>
<td>2 – 100</td>
<td>ppmw</td>
</tr>
<tr>
<td>H₂S</td>
<td>10 – 1500</td>
<td>ppmw</td>
</tr>
<tr>
<td>Total S</td>
<td>10 – 1450</td>
<td>ppmw</td>
</tr>
</tbody>
</table>

- Determine CO₂ destination
- AGR selection impact:
  - Water content impacts equipment or materials of construction
  - Suction pressure impacts compressor power
- CO₂ specification – varies by location and end-use
Air Separation Unit (ASU) Considerations

General
- Oxygen storage reduces facility-wide trips

SNG
- Oxygen purity selection impacts capital and operating cost
  - SNG at 99.8% purity to accommodate SNG pipeline spec

IGCC
- O2 Purity is typically 95% purity (knee of curve)
- N2 compression required
- Increased HP column pressure
- Air integration with combustion turbine generator

Ref. IGCC experience and related Technology Improvements for ASU,
Giovanni Massimo, Air Liquide Engineering
### E-Gas™ Technology Battery Limits (TBL)

#### General
- Full slurry quench
- Sub-bituminous, bituminous and petcoke flexible

<table>
<thead>
<tr>
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<th>SNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasifier Operating P, psig</td>
<td>665&lt;sup&gt;1&lt;/sup&gt;</td>
<td>720</td>
</tr>
<tr>
<td>SG Cooler steam P, psig</td>
<td>2000&lt;sup&gt;2&lt;/sup&gt;</td>
<td>1000&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>SG CO/H&lt;sub&gt;2&lt;/sub&gt; ratio (molar)</td>
<td>~1.7</td>
<td>~2.1</td>
</tr>
<tr>
<td>SG CH&lt;sub&gt;4&lt;/sub&gt; content</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

#### Notes
1) \( P_{op} = P_{GTG\text{ inlet}} + \Delta P \)
2) Set by bottoming cycle hp steam (IGCC)
3) Set by practical STG throttle level, 900 psig/900 F, allowing for some bypass of steam to the Shift Unit (SNG)

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E-Gas 2<sup>nd</sup> stage provides flexible syngas composition allowing high carbon capture for IGCC or increased methane for SNG
## CO Shift Area

<table>
<thead>
<tr>
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<th>IGCC</th>
<th>SNG</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of stages</td>
<td>2</td>
<td>2</td>
<td>[1] second stage is utilized in SNG case with higher bypass to optimize AGR for CO2 capture (capital cost vs. operating cost tradeoff)</td>
</tr>
<tr>
<td>Overall CO conversion, %</td>
<td>~90</td>
<td>~60</td>
<td>[2] for IGCC this value could be reduced depending on the level of CO2 capture required; for SNG, the level is determined by the CO/H2 ratio required for methanation</td>
</tr>
<tr>
<td>Feed bypass, %</td>
<td>0</td>
<td>~30</td>
<td></td>
</tr>
<tr>
<td>Steam/dry gas ratio(1st stg outlet)</td>
<td>~0.4</td>
<td>~0.4</td>
<td>[3] Values can vary greatly, depending on the CO Shift catalyst employed</td>
</tr>
</tbody>
</table>

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E-Gas Technology takes advantage of low steam/dry gas ratio for significant power savings
Acid Gas Removal (AGR) Considerations

General
- Environmental impact of solvent losses
- Trainage based on AGR selection
- Solvent cost
- CO2 specifications and venting considerations

IGCC
- Generally higher CO2 recovery
- More flexible CO2 spec in the syngas [reduced AGR cost]
- All gas shifted [separate COS hydrolysis not required]
- Generally Selexol™ is preferred for IGCC case

SNG
- Nitrogen content critical for HHV and pipeline spec
- Tight sulfur spec for methanation unit (Sulfur guard bed cost)
- CO shift by-pass requires COS mitigation
- Generally Rectisol® preferred for SNG case
CO2 Sequestration Considerations

• EOR requires CO₂ > min. miscible pressure (MMP), impacted by impurities
  - H₂, N₂, O₂, Ar, CO, and CH₄ increase MMP
  - H₂S, SO₂, and > C1 paraffin decrease MMP
  - High sulfur CO₂ may not be appropriate for sweet EOR Ops

• Storage must consider long term geochemical interaction
  - Analyze reactions & kinetics for damaging (or beneficial) rock-water interaction
  - Evaluate near wellbore reactions (possible downhole plugging)
  - Consider impact of S and O₂ species promoting bacterial impacts

• Regulatory factors
  - Rules & liability
  - Economic incentive or subsidy
Summary

- Technologies associated with gasification and CCS are ready for commercial deployment
- ConocoPhillips is developing projects that convert coal / petcoke to power and/or SNG
- Experience drawn from these projects reinforces that:
  - Optimization among process areas is key to meeting product specifications and by-product requirements
  - Flexibility of the E-Gas™ Technology facilitates optimization
  - Process AND operations knowhow from each technology area are important to successful design optimization
  - Design and operations knowhow in drilling, transportation and injection of gases is critical to developing effective CO2 sequestration schemes
- Future E-Gas™ applications will benefit from these project development activities
Sweeny IGCC/CCS Project Update

- 2+1 E-Gas™ Technology gasifiers with 3CGT x 1ST
- 6,900 st/sd pet coke to 693 MW(net)
- 85% CO$_2$ capture – store 5 million Te/yr
- Filing air permit with TCEQ 1Q 2010