<table>
<thead>
<tr>
<th>Company</th>
<th>Name</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOUTHERN COMPANY</td>
<td>Jerrad Thomas</td>
<td>PjM</td>
</tr>
<tr>
<td>MITSUBISHI HEAVY INDUSTRIES AMERICA, INC</td>
<td>Tim Thomas</td>
<td>MHI PjM</td>
</tr>
<tr>
<td></td>
<td>Shintaro Honjo</td>
<td>Process Design</td>
</tr>
<tr>
<td>AECOM</td>
<td>Katherine Dombrowski</td>
<td>AECOM PjM</td>
</tr>
<tr>
<td></td>
<td>Karen Farmer</td>
<td></td>
</tr>
<tr>
<td>NETL</td>
<td>Steve Mascaro</td>
<td>NETL PjM</td>
</tr>
</tbody>
</table>
Project Background

• Awarded Phase 1 DOE NETL Carbon Capture Program: Large-Pilot Scale Post-Combustion
  • DE-FOA-0001190
  • 10/1/15 to 10/1/16
  • Techno-Economic Assessment, EH&S Study, Tech Gap Analysis and all other Phase 1 activities complete

• Based on Phase 1 applications, DOE NETL will award Phase 2
  • Begins 10/1/16
25-MW KM-CDR at Plant Barry

- Amine-based $\text{CO}_2$ capture/compression process (MHI’s KM CDR Process®)
- Previously tested improvements such as DOE-funded HES project (with MHIA and AECOM)
Project Objectives

- Evaluate technical and economic feasibility of full-scale installation of further improvements to the KM CDR Process®
- Resolve any operational problems with improvements at 25-MW size through testing
Built-in Reboiler

- Replace regenerator reboiler and stripper with integrated unit
- Welded-plate heat exchanger, designed for high condensation or evaporation duty, installed in the column
- Reduced capital and operating cost and footprint

[Conventional vs Integrated Diagram]
Built-in Reboiler Testing Details

- **Reboiler Performance Test**
  - Confirm design performance

- **Parametric Testing**
  - Assess performance under a range of operating parameters

- **Long Term Operation Test**
  - Assess long term operability

- **Internal Inspection**
  - Inspect for potential damage or fouling
Particulate Matter (PM) Management

• Determine whether solvent purification can be eliminated
• Reduce capital and operating cost for the CCS system
• Turn off Solvent Purification System to mimic removal of the filtering process and allow PM levels in the solvent to build
• Determine maximum allowable particulate matter concentration at which solvent performance degrades
Particulate Matter Management Testing Details

- Baseline Test
  - Confirm baseline conditions and performance

- Higher PM Loading Test
  - Measure PM concentration and suspended solids (SS), and monitor conditions and performance without Solvent Purification System (SPS)

- Reclaiming Test
  - Operate reclaimer to remove and analyze SS

- Inspection
  - Conduct internal inspection potential damage, accumulation or fouling.
New Solvent A Testing

• Replace KS-1™ solvent with improved amine-based New Solvent A developed by MHIA

\[
\begin{align*}
\text{Mono-ethanol Amine (MEA)} & \\
2 \text{R-NH}_2 + \text{CO}_2 & \rightleftharpoons 2 \text{R-NH}_3^+ + \text{R-NH-COO}^- & \text{(Dominant Reaction = 2:1)} \\
\text{R-NH}_2 + \text{CO}_2 + \text{H}_2\text{O} & \rightleftharpoons \text{R-NH}_3^+ + \text{HCO}_3^- & \text{(Subordinate reaction = 1:1)} \\
\text{Sterically Hindered (KS-1, New Solvent A)} & \\
2 \text{R-NH}_2 + \text{CO}_2 & \rightleftharpoons 2 \text{R-NH}_3^+ + \text{R-NH-COO}^- & \text{(Dominant Reaction = 2:1)} \\
\text{R-NH}_2 + \text{CO}_2 + \text{H}_2\text{O} & \rightleftharpoons \text{R-NH}_3^+ + \text{HCO}_3^- & \text{(Subordinate reaction = 1:1)}
\end{align*}
\]
Advantages of New Solvent A

- New Solvent A regeneration steam consumption
  - Reduced 5% from KS-1™
  - Reduced 37% from MEA
- Steam consumption savings significantly outweigh cost increases due to higher solvent circulation
- New Solvent A potentially more tolerant to impurities

<table>
<thead>
<tr>
<th></th>
<th>MEA</th>
<th>KS-1™</th>
<th>New Solvent A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Consumption</td>
<td>1</td>
<td>0.68</td>
<td>0.63</td>
</tr>
<tr>
<td>Solvent Degradation</td>
<td>1</td>
<td>0.1</td>
<td>0.05</td>
</tr>
<tr>
<td>Solvent Emission</td>
<td>1</td>
<td>0.1</td>
<td>0.04</td>
</tr>
</tbody>
</table>
New Solvent A Testing Details

- **Baseline Test**
  - Confirm baseline performance of New Solvent A

- **Optimization Test**
  - Vary operating parameters to verify performance

- **Long Term Operation Test**
  - Confirm performance and verify solvent degradation rate

- **Reclaiming Test**
  - Perform reclaiming operation to confirm operability and stability.

- **Inspection**
  - Conduct internal inspection for potential corrosion
Phase 2 (BP2-BP4) will last 4 years (10/1/16-9/30/20)

BP2-BP4 Costs

- DOE Share: $18,000,000 (80%)
- Cost Share: $4,500,000 (20%)
Phase 2 Schedule

- **Engineering**
  - Oct 2016 - Apr 2017

- **Procurement, Construction**
  - Apr 2017 - Dec 2017

- **Commissioning and Operations**
  - Jan 2018 - Oct 2019

- **Field Testing and Analysis**
  - Apr 2018 - Dec 2019

- **Decommissioning**
  - Jan 2020 - Sept 2020

All Phase 1 activities complete
Engineering pending Phase 2 award September 2016
## Phase 2 Milestones

<table>
<thead>
<tr>
<th>Milestone Description</th>
<th>Planned Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detailed Engineering Start</td>
<td>10/1/16</td>
</tr>
<tr>
<td>Detailed Engineering Complete</td>
<td>3/30/17</td>
</tr>
<tr>
<td>Mobilize General Contractor</td>
<td>4/1/17</td>
</tr>
<tr>
<td>Mechanical Completion</td>
<td>12/31/17</td>
</tr>
<tr>
<td>BIR-PMM Commissioning Complete</td>
<td>1/30/18</td>
</tr>
<tr>
<td>NSL Commissioning Complete</td>
<td>4/30/19</td>
</tr>
<tr>
<td>BIR-PMM Baseline Evaluation Complete</td>
<td>4/30/18</td>
</tr>
<tr>
<td>BIR-PMM Testing Complete</td>
<td>10/31/18</td>
</tr>
<tr>
<td>BIR-PMM Data Analysis Complete</td>
<td>12/31/18</td>
</tr>
<tr>
<td>NSL Baseline Evaluation Complete</td>
<td>4/30/19</td>
</tr>
<tr>
<td>NSL Testing Complete</td>
<td>10/31/19</td>
</tr>
<tr>
<td>NSL Data Analysis Complete</td>
<td>12/31/19</td>
</tr>
<tr>
<td>Decommissioning Complete</td>
<td>9/30/20</td>
</tr>
<tr>
<td>Final TEA and EH&amp;S Complete</td>
<td>9/30/20</td>
</tr>
<tr>
<td>Date</td>
<td>Category</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>3/31/17</td>
<td><strong>Engineering:</strong> Completion of engineering with cost estimate for large-scale pilot program within budget.</td>
</tr>
<tr>
<td>12/31/17</td>
<td><strong>Procurement and Construction:</strong> Completed within target budget and adhering to desired design.</td>
</tr>
<tr>
<td>12/31/18</td>
<td><strong>Built-In-Reboiler Performance:</strong> Measured initial heat transfer efficiency and steam consumption matches or is less than non-integrated reboiler.</td>
</tr>
<tr>
<td></td>
<td><strong>Particulate Matter Management Evaluation:</strong> Ability to remove solvent filters confirmed and maximum PM level established.</td>
</tr>
</tbody>
</table>
## Phase 2 Success Criteria

### 12/31/19

**New Solvent Performance:** Confirm reduction in regeneration steam consumption (5% over KS-1™ and 37% over MEA).

**New Solvent Long Term Operation:** Long-term stability of new solvent with regard to degradation.

### 9/30/20

**Overall Cost Performance:** Revised final TEA shows implementation of 3 improvements with heat integration achieves $54.8/tonne CO2 and 12.7% reduction in COE.

**Inspection:** No significant corrosion, scaling or impurity buildup due to testing.
Phase 1 Technology Gap Analysis

- Analyzed technical gaps and determined that there were no major gaps remaining prior to testing at 25-MW scale

<table>
<thead>
<tr>
<th>ACC Technology Component</th>
<th>Technology Readiness Level</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built-in Reboiler</td>
<td>6</td>
<td>Commerciaally available; tested at 2.5-MW scale for amine-based CO₂ removal on coal-fired flue gas</td>
</tr>
<tr>
<td>Particulate Matter Management</td>
<td>6-7</td>
<td>Long-term testing of effects of PM concentration with CAFS has been completed at 25-MW pilot; PM concentration will be increased gradually without filtering; lab testing is not applicable to this component</td>
</tr>
<tr>
<td>New Solvent A</td>
<td>5</td>
<td>Tested at 0.1-MW scale on natural-gas fired flue gas for CO₂ removal</td>
</tr>
</tbody>
</table>
Phase 1 updates to the technology economics (2011 dollars)

<table>
<thead>
<tr>
<th>DOE Targets</th>
<th>Supercritical PC w MEA CCS (Case 12)</th>
<th>Supercritical PC w KM-CDR CCS with HES</th>
<th>Supercritical PC w KM-CDR CCS with HES, BIR, PMM and NSL + Aux. Turbine</th>
<th>Supercritical PC w KM-CDR CCS with HES, BIR, PMM and NSL + Aux. Turbine</th>
</tr>
</thead>
<tbody>
<tr>
<td>COE (mils/kW)</td>
<td>147.3</td>
<td>133.7</td>
<td>130.6</td>
<td>128.6</td>
</tr>
<tr>
<td>Cost of CO₂ capture ($/tonne)</td>
<td>66.4</td>
<td>58.8</td>
<td>56.0</td>
<td>54.8</td>
</tr>
</tbody>
</table>
Summary

• Completed Phase 1 Techno-Economic Assessment, EH&S Study, Tech Gap Analysis and updated project budget
• Phase 2 Engineering will begin pending Phase 2 award
• Phase 2 complete by end of September 2020
Questions?