Advanced Solvent Based Carbon Capture Technology Development

DE-FE0026590

Project Review Meeting

August 9, 2016

SOUTHERN COMPANY

Project Team

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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

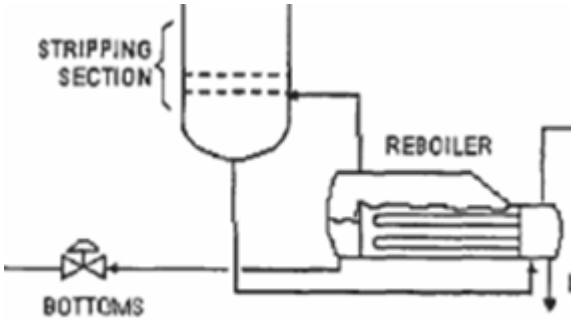
- Amine-based CO_2 capture/compression process (MHI's KM CDR Process®)
- Previously tested improvements such as DOE-funded HES project (with MHIA and AECOM)

Project Objectives

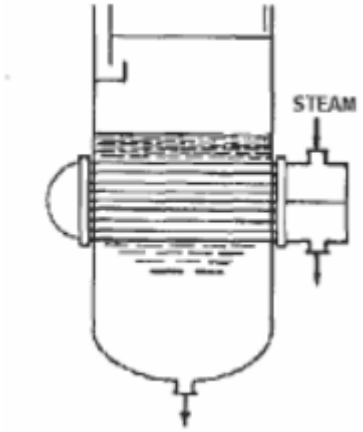
- Evaluate technical and economic feasibility of full-scale installation of further improvements to the KM CDR Process®
- Resolve any operational problems with improvements at 25-MW size through testing

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



Integrated

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

- **Mono-ethanol Amine (MEA)**

  $2\ R\text{-}NH_2 + CO_2 \rightleftarrows 2\ R\text{-}NH_3^+ + R\text{-}NH\text{-}COO^-$ (Dominant Reaction = 2:1)

  $R\text{-}NH_2 + CO_2 + H_2O \rightleftarrows R\text{-}NH_3^+ + HCO_3^-$ (Subordinate reaction = 1:1)

- **Sterically Hindered (KS-1, New Solvent A)**

  $2\ R\text{-}NH_2 + CO_2 \rightleftarrows 2\ R\text{-}NH_3^+ + R\text{-}NH\text{-}COO^-$ (Dominant Reaction = 2:1)

  $R\text{-}NH_2 + CO_2 + H_2O \rightleftarrows R\text{-}NH_3^+ + HCO_3^-$ (Subordinate reaction = 1:1)

Advantages of New Solvent A

Comparison of Solvent Characteristics

	MEA	KS-1™	New Solvent A
Steam Consumption	1	0.68	0.63
Solvent Degradation	1	0.1	0.05
Solvent Emission	1	0.1	0.04

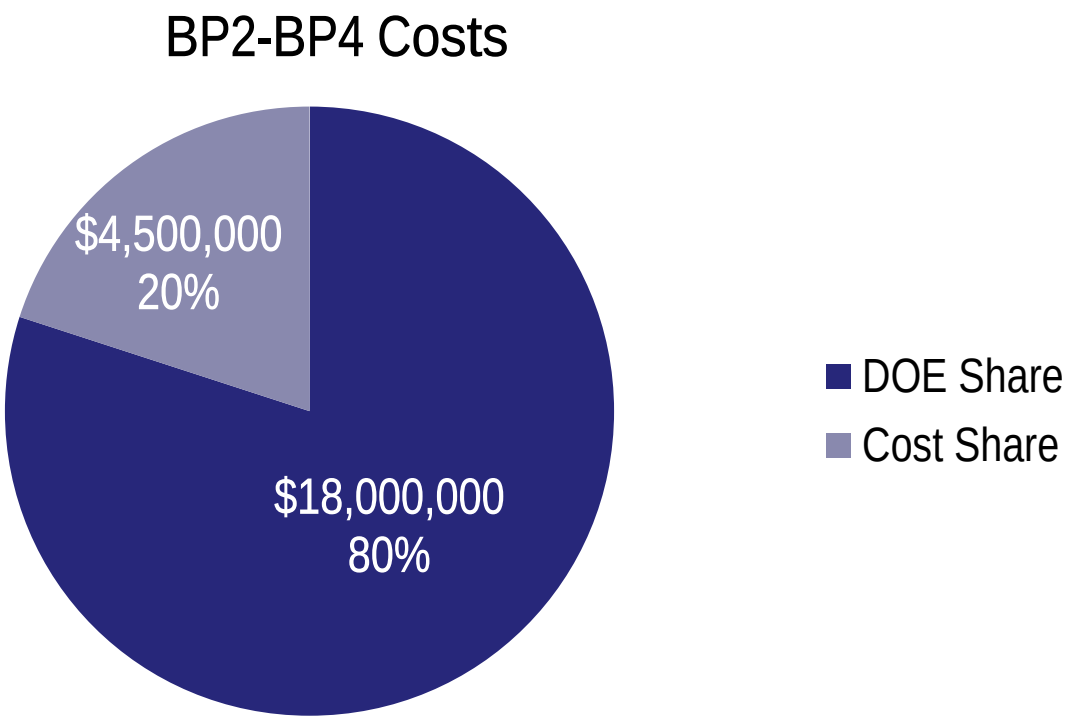
- New Solvent A regeneration steam consumption
  - Reduced 5% from KS-1™
  - Reduced 37% from MEA
- Steam consumption savings significantly outweigh cost increases due to higher solvent circulation
- New Solvent A potentially more tolerant to impurities

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

Project Structure: Phase 2 Budget

Phase 2 (BP2-BP4) will last 4 years (10/1/16-9/30/20)



Phase 2 Schedule

All Phase 1 activities complete

Engineering pending Phase 2 award September 2016

Phase 2 Milestones

Milestone Description	Planned Completion Date
Detailed Engineering Start	10/1/16
Detailed Engineering Complete	3/30/17
Mobilize General Contractor	4/1/17
Mechanical Completion	12/31/17
BIR-PMM Commissioning Complete	1/30/18
NSL Commissioning Complete	4/30/19
BIR-PMM Baseline Evaluation Complete	4/30/18
BIR-PMM Testing Complete	10/31/18
BIR-PMM Data Analysis Complete	12/31/18
NSL Baseline Evaluation Complete	4/30/19
NSL Testing Complete	10/31/19
NSL Data Analysis Complete	12/31/19
Decommissioning Complete	9/30/20
Final TEA and EH&S Complete	9/30/20

Phase 2 Success Criteria

3/31/17	**Engineering:** Completion of engineering with cost estimate for large-scale pilot program within budget.
12/31/17	**Procurement and Construction:** Completed within target budget and adhering to desired design.
12/31/18	**Built-In-Reboiler Performance:** Measured initial heat transfer efficiency and steam consumption matches or is less than non-integrated reboiler. **Particulate Matter Management Evaluation:** Ability to remove solvent filters confirmed and maximum PM level established.

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 build-up 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

ACC Technology Component	Technology Readiness Level	Evidence
Built-in Reboiler	6	Commercially available; tested at 2.5-MW scale for amine-based CO_2 removal on coal-fired flue gas
Particulate Matter Management	6-7	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
New Solvent A	5	Tested at 0.1-MW scale on natural-gas fired flue gas for CO_2 removal

Phase 1 Techno-Economic Assessment

- Phase 1 updates to the technology economics (2011 dollars)

	Supercritical PC w MEA CCS (Case 12)	Supercritical PC w KM-CDR CCS with HES	Supercritical PC w KM-CDR CCS with HES, BIR, PMM and NSL	Supercritical PC w KM-CDR CCS with HES, BIR, PMM and NSL + Aux. Turbine	DOE Targets
COE (mils/kW)	147.3	133.7	130.6	128.6	103.1 by 2030 (-30% from Case 12)
Cost of CO_2 capture ($/tonne)	66.4	58.8	56.0	54.8	40.0 by 2025 30.0 by 2030

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?