Development and Demonstration of Waste Heat Integration with Solvent Process for More Efficient CO$_2$ Removal from Coal-Fired Flue Gas

DE-FE0007525

Project Review Meeting

June 24, 2015
Heat Integration with 25 MW KM-CDR at Plant Barry

- Funded by industry consortium
- Fully integrated CO₂ capture/compression
- Storage in Citronelle Dome
- 500 metric tons CO₂/day
Project Participants

Nick Irvin
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Mandi Richardson
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Tim Thomas
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Total Project Budget ($MM)

- 12.3
- 3.6

- DOE Share
- Cost Share
Waste heat sources include flue gas and CCS plant streams.
Boiler feed water will be heated with CO₂ Cooler and Flue Gas Cooler

**CO₂ Cooler**
Standard heat exchanger

**Flue Gas Cooler**
MHI proprietary heat exchanger
Flue Gas Cooler proven on low S coals

Carbon steel tubes in good condition after 2 years operation at Japanese plant

What happens with higher sulfur coals fired in US?
FGC Requires High D/S Ratio

Example:
Dust : 9000-14000 mg/Nm\(^3\)
\[ \text{H}_2\text{SO}_4 = 30 \times 98 / 22.4 / 0.8 = 164 \text{ mg/Nm}^3 \]
D/S ratio = 55 – 85

Plant firing 2.5% S fuel

Uncertainty around the reliability of the system with higher sulfur fuels (> 1% S)
Flue Gas Cooler captures SO$_3$

- Operates downstream of the APH
- Mechanism for removal of SO$_3$ from flue gas
  - $SO_3$ (g) + $H_2O$ (g) --> $H_2SO_4$ (g)
  - $H_2SO_4$ (g) --> $H_2SO_4$ (l)
  - $H_2SO_4$ (l) condenses on fly ash in flue gas and a protective layer of ash on tube bundles
- Flue Gas Cooler tube skin temperature $<$ SO$_3$ dewpoint
  - Alkaline species in fly ash (Ca, Na) neutralize $H_2SO_4$
  - Silicates, etc. physically adsorb $H_2SO_4$
Other benefits of Flue Gas Cooler

- Improve removal of Hg, Se, SO$_3$ across the ESP
- Reduce AQCS cost
  - Improve ESP performance
  - Improve FGD performance
  - Improve CCS performance
- Potential to simplify boiler/steam turbine cycles
- Improve plant heat rate
Heat integration eliminates LP heaters

From IP Steam Turbine

LP Steam Turbine

LP Heater 4 → LP Heater 3 → LP Heater 2 → LP Heater 1 → Condenser

To Deaerator
Heat integration eliminates LP heaters

1-3
Heat integration eliminates LP heaters
Heat integration increases plant efficiency

- Reduced steam extractions for:
  - BFW heating
  - CCS solvent regeneration

Net Plant HHV Efficiency (%):

- CCS: 28.9
- CCS + FGC + CO2 Cooler: 29.7
Heat integration decreases cost of CCS

Analysis per 2010 DOE Cost and Performance Baseline
Heat Integration Challenges

• Highly integrated systems incorporating waste heat recovery have yet to be demonstrated at any scale in the U.S.
• Overcome skepticism in U.S. by proving system reliability
• Process control during transients/perturbations, which are typical in power plant operations
• Removal performance of specific impurities not yet quantified for varying operating conditions
• Uncertainty around the reliability of the system with higher sulfur fuels (> 1% S)
Project Objectives

Quantify tangential benefits
- Better ESP performance
- Increase SO₃, Hg, Se capture
- Reduce CCS solvent consumption
- Reduce FGD H₂O consumption

Resolve operational problems of integration

Quantify energy efficiency improvements
PROJECT = Boiler feed water will be heated with CO₂ Cooler and Flue Gas Cooler
Flue gas dampers
Flue Gas Cooler shell fabrication
Flue Gas Cooler Installed
CO₂ Cooler General Arrangement

- CO₂ Cooler
- Plant Barry
- Regenerator
- CO₂ Absorber
CO₂ Cooler Installed
BP3 completes March 2016

BP1
- FEED and Target Cost Estimate
- Permitting

BP2
- Engineering, Procurement, Construction

BP3
- Operations
- Field Testing Analysis
Remaining project work

Complete Construction
Dec 2014 - June 2015

Commission
June 2015 - June 2015

Operations and Testing
June 2015 - Nov 2015

- Verify efficiency
- Estimate reduction in FGD water use
- Measure corrosion, erosion
- Test water quality
- Measure SO$_3$, trace metal removal
Test Program

• Performance
  – Verify max heat recovery performance and controllability of TCV
  – Water consumption reduction to FGD, cooling water reduction to Quencher
  – Boiler condensate water quality and tube leak potential
  – Total economic evaluation

• Turndown Load Operation
  – Confirm heat recovery performance at turndown load (same items as above)

• Impurities Removal
  – Verify ESP performance (ash characteristics, trace metals removal, impact of Br injection)

• Long Term Durability

• Material Evaluation