Co-Gen Wastewater Treatment for Coal-Fired Energy Plants Project

• Type of Contract:
  • DOE Co-Op (DOE/NETL)

• Period of Performance:
  • October, 2018 to March, 2021

• Total Contract Value:
  • $748.8K PLUS $187.2K Cost Share
Project Objectives

• Show clear, economic solution for FGD wastewater treatment supported by detailed analyses and trade studies
  • Review system configuration options
  • Select an optimized solution

• Complete experiments to document the solubility, transport and/or capture of Critical Pollutants of Concern (CPoC) species
  • Liquid and gas phase
  • Information will be essential to guide work on the first objective and determine economic options for CPoC removal
Project Approach

- Innovative process will reduce the net cost of water treatment
  - Process has similar CAPEX to current chemical/biological systems
  - Generate power to offset capital investment and operational expenses
  - Portion of the wastewater stream will be heated and filtered and then used as a working fluid in a turbine
- Verify concept makes economic sense
  - Complete system modeling and economic assessment of options
  - System study and economic evaluation will define the most attractive system configuration
- Address a key implementation risk
  - Investigate additives in the case that some CPoC are not readily separated from the steam stream
  - Complete Filter Testing and Analysis
    - Size/Design/Procure/Fabricate Test System
Proposed System Configuration

- **Heat Recovery**: Gas turbine exhaust heat recovery resembles HRSG, but does not boil wastewater.
  - **HRSG**: 181°F, ~3200 psi, ~470°F

- **Power Generation**: Surplus power (17 MWe net) offsets Fuel and Capex.
  - **Motor Generator**: ~54 MWth, 220 psi, 1750°F

- **Direct Fired Superheater**: ~6 MWth, 240 psi, 780°F

- **Solids Separator**: Fabric filters for low solids loading. Add Cyclones for higher solids loading.
  - **Wastewater**: ~3200 psi, ~700°F, ~300 psi, 418°F

- **Flash Separator**: Concentrates brine (via pressure letdown) before sending to steam generator. Lowers Fuel Consumption.
  - **Brine**: ~5x Conc., 300 psi, 418°F

- **Wastewater Discharge**: Natural Gas IN (60 MWth)

- **Cooling Water**: Clean Water

- **Condensing Heat Exchanger**: Steam Discharge, ~2600 psia, ~675°F
Hardware Assembly

- Test input – simulated or actual FGD water
- Heat water to conditions similar to direct steam generator system
- Filter steam/combustion stream with candle filters as planned
- Evaluate success capturing CPoC
Testing Summary – Simulated FGD Water

• Focused on Effluent Limitation Guidelines from the 2015 Rule
  • Hg & Se - added As, Nitrates, other pollutants in later tests
• Completed 12 simulated water filtering tests
  • Examined three nozzles and three filters
  • Selected filter and nozzle for actual FGD water testing
  • Typically captured >83% of the water and solids (vapor small/not measured)
• Optimized test apparatus through simulated water testing
• Typical TDS results - Before ~27,000 ppm; After ~234 ppm
  • Se meets release criteria
  • Hg does not meet release criteria – very stringent
  • As meets criteria
  • Nitrates higher than release criteria
• Water available for re-use in the facility – reduce fresh water needed
Solids Summary
Broad size distribution good for candle filter
Solids Summary
Particle size analysis by XRD

![Histogram of particle size distribution](Lot 202589-009)
Testing Summary – Actual FGD Water

• Completed 2 tests on AEP produced water and one test on EPRI-1.
  • Utilized a guard bed of HGR carbon to address mercury content in vapor phase.
  • Ran AEP a second time due to a wet filter cake and solids migrating through the filter.

• TDS reduction
  • EPRI-1 6,570 ppm before; 100 ppm after
  • AEP Test 2 – 18,000 ppm before; 240 ppm after

• Critical Pollutants of Concern
  • Se meets release criteria
  • Hg does meet criteria for effluent water
    • Hg HGR carbon treatment for vapor
  • As meets criteria
  • Nitrates met criteria

• Water available for re-use in the facility – reduce fresh water needed
**System Performance - CPoC**

<table>
<thead>
<tr>
<th></th>
<th>TDS</th>
<th>Se</th>
<th>Hg</th>
<th>As</th>
<th>Nitrates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>After</td>
<td>Initial</td>
<td>After</td>
<td>Initial</td>
</tr>
<tr>
<td>AEP **</td>
<td>20,000</td>
<td>5700</td>
<td>0.180</td>
<td>0.1060</td>
<td>0.00333</td>
</tr>
<tr>
<td>AEP (2)</td>
<td>18,000</td>
<td>240</td>
<td>0.142</td>
<td>0.0039</td>
<td>0.00200</td>
</tr>
<tr>
<td>EPRI_1</td>
<td>6,570</td>
<td>100</td>
<td>0.094</td>
<td>&lt;.0025</td>
<td>0.00094</td>
</tr>
<tr>
<td>Req’t *</td>
<td>Not applicable</td>
<td>0.0075 mg/L</td>
<td>.000159 mg/L</td>
<td>0.00598 mg/L</td>
<td>1.3 mg/L</td>
</tr>
</tbody>
</table>

Black = initial values or not applicable/unknown/reference, **Red = does not meet, blue = meets**

* EPA 2015 rule

** Filter breached by liquid – operational issue, not a valid test

- Cr increased in each test, ranged from 0.37-3.09 mg/L vs 0.1 mg/L requirement for EPA drinking water
- Ph ranged from 1.66-2.37, too low to release
Summary of Effluent Results
Mercury Analysis

- Water and solid samples indicate Hg in vapor form as feared/expected.
- EPRI1-1 passed criteria without need for treatment.
- AEP2 passes criteria after treatment with HGR carbon.

<table>
<thead>
<tr>
<th></th>
<th>Synthetic Feed Water, mg/L</th>
<th>Hg Gas Phase No Guard (sorbent), ug/L gas</th>
<th>Hg Gas Phase With Guard (sorbent), ug/L gas</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEP1</td>
<td>0.00333</td>
<td>0.001244</td>
<td>0.0005627</td>
<td>0.54766881</td>
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<tr>
<td>AEP2</td>
<td>0.00202</td>
<td>0.00158</td>
<td>0.000095</td>
<td>0.94025892</td>
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<tr>
<td>EPRI1-1</td>
<td>0.000936</td>
<td>0.000102</td>
<td>0.00003</td>
<td>0.70588235</td>
</tr>
</tbody>
</table>
Summary

- Candle filter system captures majority of water contaminants
- TDS reduction to < ~250 ppm
- Critical Pollutants of Concern
  - Se meets release criteria
  - Hg meets criteria
    - Treat vapor with HGR carbon treatment
  - As meets criteria
  - Nitrates met criteria in one case
- Water available for re-use in the facility – reduce fresh water needed - or release
  - Ph is low – need to adjust prior to release
  - Cr is high – leaching from un-passivated tubing?
- Need to complete economic assessment to show viability
Next steps

• Complete analysis of results
• Complete TEA
  • Modify system model to include HGR Carbon addition
• Complete final report
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