Hybrid and Advanced Air Cooling

Project Officer: Tim Reinhardt
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This presentation does not contain any proprietary confidential, or otherwise restricted information.
Cooling water is a key limiting resource for geothermal power plant development.

Air cooling is expensive and suffers performance declines during hot days (typically utility peak load).

Hybrid cooling uses a limited amount of water to improve performance, but has not been a commercial success due to:

- Corrosion,
- Scaling, and
- Water shortage.

California utilities are beginning to see geothermal as non-baseload resource due to this impact.
Scientific/Technical Approach

Original Scope

1. Analysis ($417K)
Create models, evaluate alternative configurations, and select best options.

2. Field Test Design ($458K)
Identify appropriate test site, negotiate access, design test equipment, and develop test plan.

3. Field Test Installation and testing ($650K)
Install test equipment, test during summer months, and collect and analyze data.

Revised Scope

1. Analysis ($459K)
Create models, evaluate alternative configurations, and select best options.

2. Field Test Design ($328K)
Operational problems at test site (RMOTC) led to termination of Task 2 and rescoping project.

3. Innovative Design Options ($292K)
Install test equipment, test during summer months, and collect and analyze data.

Original Budget $1,525K
Revised Budget $1,079K
Scientific/Technical Approach

- Literature review and identification of design options.
- Development of ASPEN performance simulation models.
- Cost estimation and economic evaluation.
- Design for testing (scope revision).
- Innovative design options –
  - CFD models,
  - Aspen models.

NOTE: With revised scope, the project became analysis and conceptual design.
Accomplishments, Results, and Progress

<table>
<thead>
<tr>
<th>System</th>
<th>Incremental Equipment Cost</th>
<th>Incremental Revenue (TOD)</th>
<th>Payback Period</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplemental Condenser</td>
<td>2.1</td>
<td>0.36</td>
<td>6</td>
<td>No need for R&amp;D</td>
</tr>
<tr>
<td>Wetted-Media</td>
<td>3.3</td>
<td>0.36</td>
<td>9</td>
<td>Expensive</td>
</tr>
<tr>
<td>Fogging</td>
<td>2.2</td>
<td>0.36</td>
<td>6</td>
<td>Expensive</td>
</tr>
<tr>
<td>Spray</td>
<td>0.21</td>
<td>0.36</td>
<td>1</td>
<td>Least cost/possible Corrosion</td>
</tr>
<tr>
<td>Deluge#</td>
<td>0.06</td>
<td>0.51</td>
<td>1</td>
<td>Corrosion</td>
</tr>
</tbody>
</table>

* All systems use about 10.5 million gallons of water and produce 1350 MWh additional electricity per year.

# Deluge system yielded 1900 MWh additional electricity. It is prone to cause corrosion of the condenser tube and fins.
Accomplishments

Potential cost reduction for ACC – by eliminating subcooling

Folded Tube Arrangement

Heat transfer over length

Geometry of heat exchanger

This idea was the subject of a record of invention late in the project
Accomplishments

Multi-pass Vapor flow Advantages

- About 20% less tube length
- Lower height
- Potential reduced costs
## Accomplishments, Results, and Progress

<table>
<thead>
<tr>
<th>Original Planned Milestone/Technical Accomplishment</th>
<th>Actual Milestone/Technical Accomplishment</th>
<th>Date Completed</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>GRC paper presentation</td>
<td>Oct 2011</td>
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<tr>
<td>Task 2 field site design, 9/30/2011</td>
<td>Operational/budget problems at RMOTC test site led to revision of project scope</td>
<td>9/30/2011</td>
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<tr>
<td>Task 3 final report, 12/30/2012</td>
<td>Report completed</td>
<td>1/30/2013</td>
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<tr>
<td></td>
<td>Two records of invention filed, one provisional patent filed</td>
<td>1/30/2013</td>
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<tr>
<td>Task 3 report publication, March 2013</td>
<td>Publication behind schedule due to additional reviews with inventions</td>
<td></td>
</tr>
</tbody>
</table>
Future Directions

• Publication of results at conferences.

• Decision on patent application and working with industry to commercialize.

• Identify industry partners for cost-shared testing and development of innovative concepts.

• Possible uses for other applications (e.g., HVAC) can improve economics.
1. NREL has arrived at a cost-optimum, practical, and convenient means for implementation of hybrid cooling via methods described in IP documents.

2. DOE/NREL aims to promote initial implementation and wider adaptation of this cost-effective hybrid cooling option.
Frequent communications with DOE during Task 2 were essential in developing new work scope and reducing project budget.

During the project, we have had multiple meetings and discussions with the geothermal industry. The feedback and critiques received were invaluable.