Hybrid and Advanced Air Cooling

Project Officer: Tim Reinhardt
Total Project Funding: $1079K
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ARRA funded

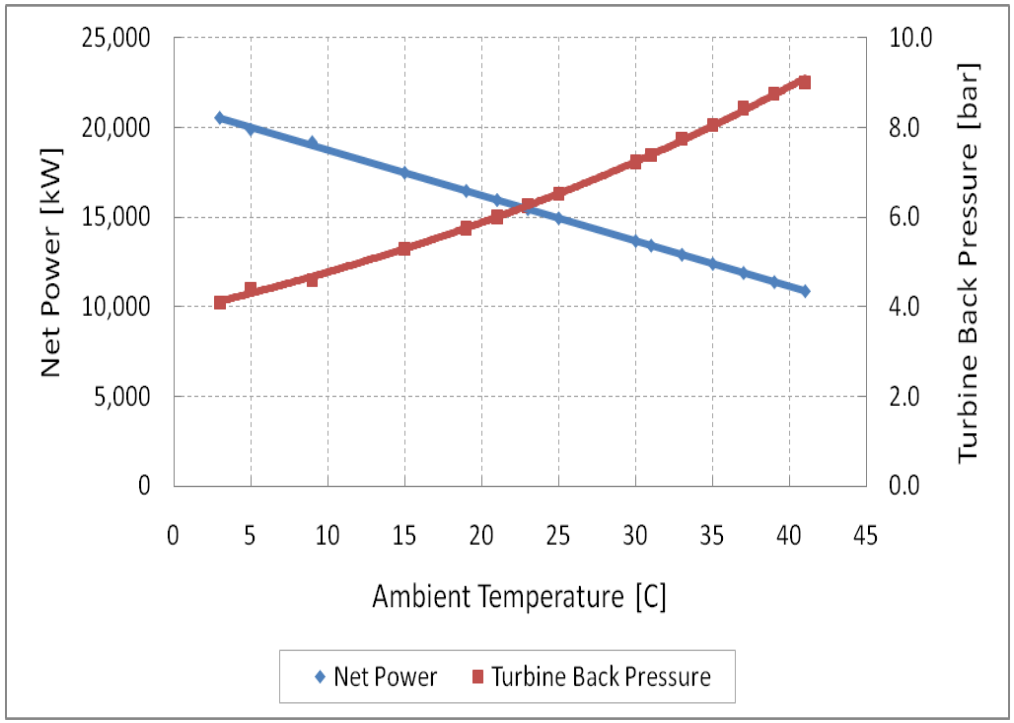
Relevance/Impact of Research

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.



Study results for a 20-MW air cooled power plant simulation.

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.

Original Budget $1,525K

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)

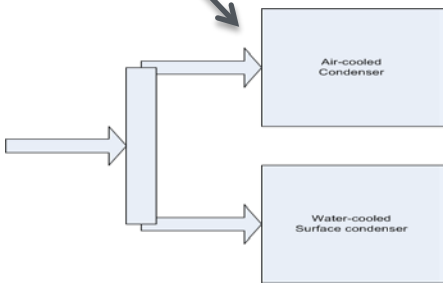
Install test equipment, test during summer months, and collect and analyze data.

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.

Spray/Fog
Wetted media
Deluge
Supplemented



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

Accomplishments, Results, and Progress

System	Incremental Equipment Cost	Incremental Revenue (TOD)	Payback Period	Remarks
	(M$)	(M$/yr)	(yr)	
Supplemental Condenser	2.1	0.36	6	No need for R&D
Wetted-Media	3.3	0.36	9	Expensive
Fogging	2.2	0.36	6	Expensive
Spray	0.21	0.36	1	Least cost/possible Corrosion
Deluge#	0.06	0.51	1	Corrosion

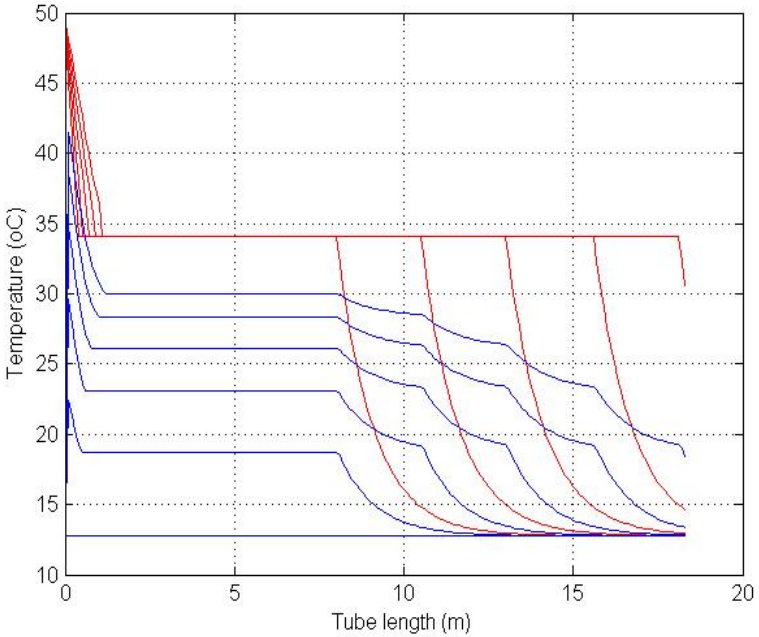
* All systems use about 10.5 million gallons of water and produce 1350 MWh additional electricity per year.

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

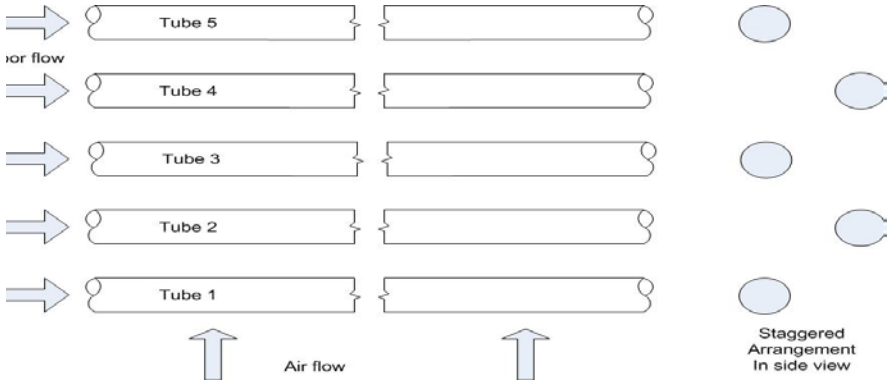
Accomplishments

Potential cost reduction for ACC – by eliminating subcooling

Folded Tube Arrangement



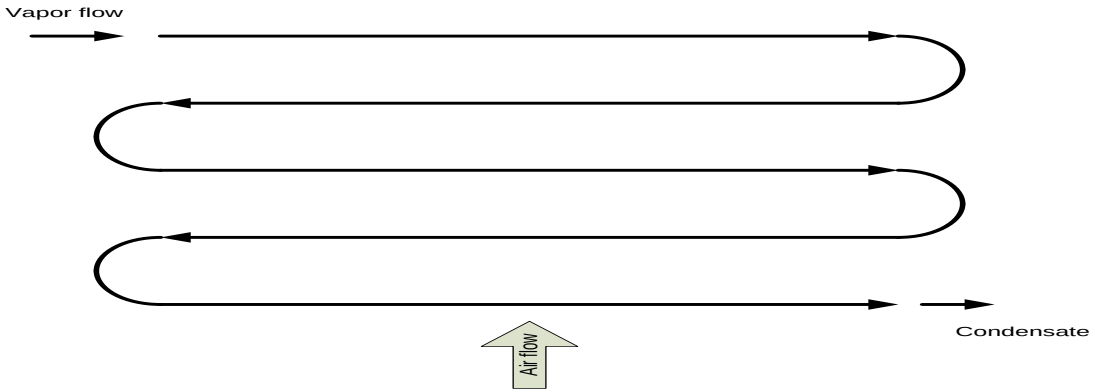
Heat transfer over length



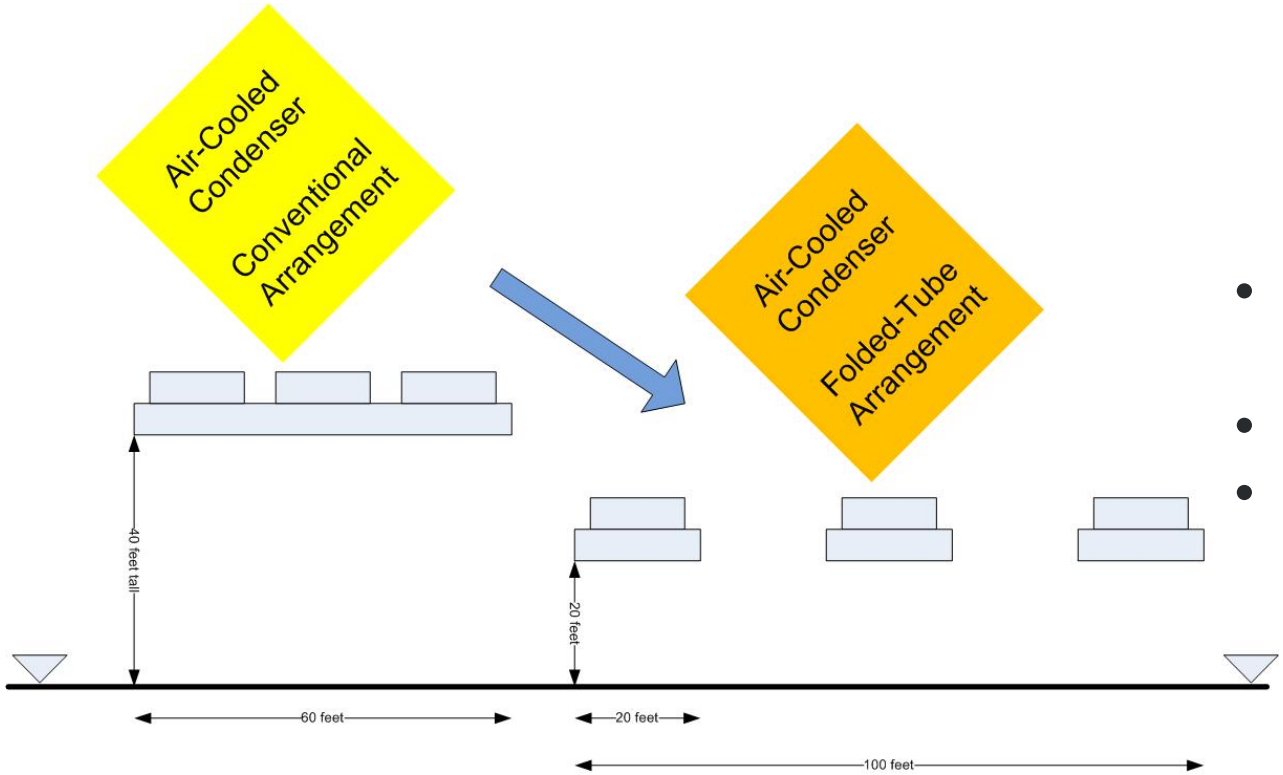
Geometry of heat exchanger

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

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Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Task 1 final report, 9/30/2010	Report completed and published	2/25/2011
	GRC paper presentation	Oct 2011
Task 2 field site design, 9/30/2011	Operational/budget problems at RMOTC test site led to revision of project scope	9/30/2011
Task 3 final report, 12/30/2012	Report completed	1/30/2013
	Two records of invention filed, one provisional patent filed	1/30/2013
Task 3 report publication, March 2013	Publication behind schedule due to additional reviews with inventions	

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.

R&D Summary

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.

Project Management

Timeline:

Planned Start Date	Planned End Date	Actual Start Date	Current End Date
10/1/09	9/30/12	10/1/09	1/30/13

Budget:

Federal Share	Cost Share	Planned Expenses to Date	Actual Expenses to Date	Value of Work Completed to Date	Funding needed to Complete Work
$1,079,000	$0	$1,037,000	$1,037,000	$1,022,400	$0

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.