



## Novel Energy Conversion Equipment for Low Temperature Geothermal Resources

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Jay Kohler

**Frank Baumgardt**  
**Johnson Controls, Inc.**

Geothermal Energy Production from Low  
Temperature Resources

## Timeline:

This project was awarded on April 30, 2010.

Manufacturing of both prototype units is complete. Shipment to OIT is planned for summer 2013 (due to delays outside of DOE scope).

## Budget

Total Project Cost: \$2,172,423

DOE Share: \$1,047,714

>90% Spent as of 3/2013

## Barriers

High cost of electricity generation  
reduces utilization of low-temperature  
geothermal resources

## Partners

Barber-Nichols, Inc., Oregon Institute of  
Technology

## Objective

- Develop equipment that generates electricity from low temperature geothermal resources at a cost at least 20% below that of the currently available technology.

## Geothermal Program Goal:

- “Develop low-cost, high efficiency energy conversion technologies for EGS”

## Planned Research Results:

- (1) better working fluids and
- (2) improved cycle heat management.

- Johnson Controls leverages decades of experience in developing and manufacturing commercial chiller equipment to identify and implement the equipment modifications required to generate electricity.
- Our partners contribute specialized expertise (e.g. Barber Nichols for turbine development)

## Progress:

Manufacturing of both prototype units has been completed.

## Expected Outcome:

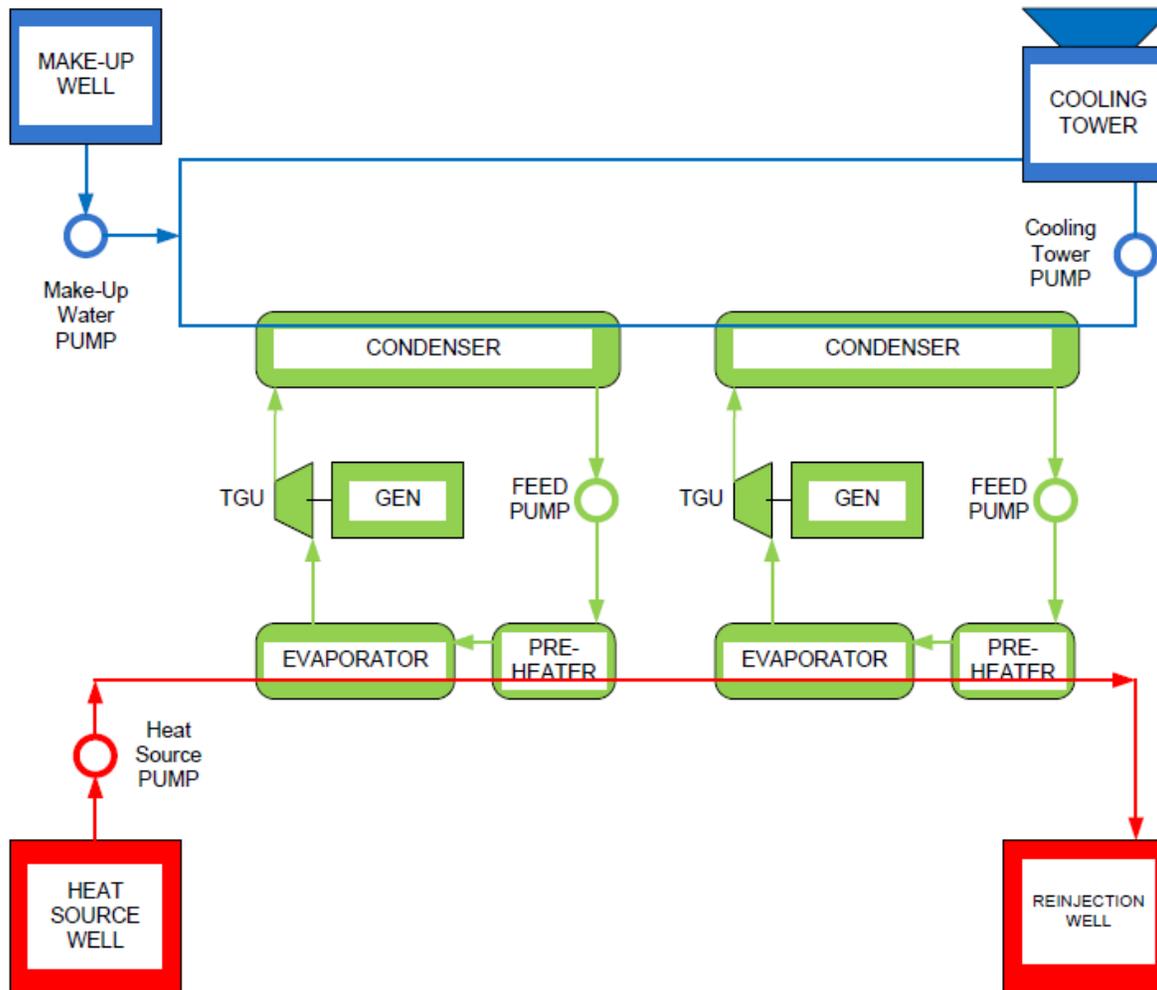
Commercial product that can generate electricity from low-temperature geothermal resources at costs 20% below the current state of the art.

## Accomplishments:

- Modeling results show achievement of 20% improvement goal. Lab testing exceeded modeled results.
- Research resulted in novel **series-counterflow** configuration of managing cooling water and brine flow with substantial gains in efficiency (patent pending).

# Series- Counterflow Configuration:

ORC Power Generation System: Series Arrangement



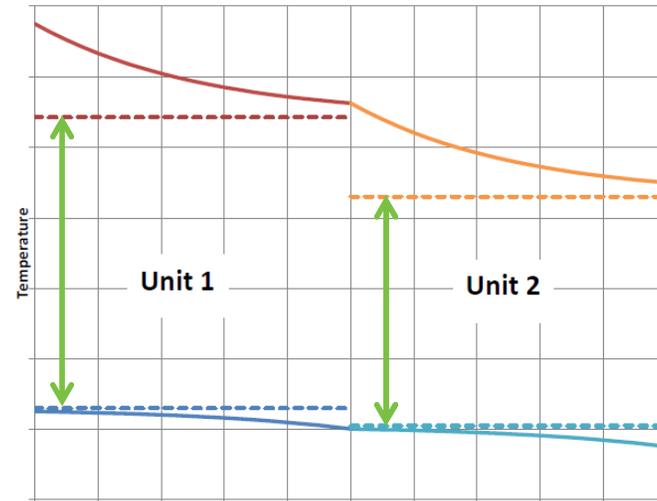
# Series-Counterflow Benefit:

Parallel Arrangement



— Unit 1 Heating - - - Unit 1 TH — Unit 2 Heating - - - Unit 2 TH  
— Unit 1 Cooling - - - Unit 1 TC — Unit 2 Cooling - - - Unit 2 TC

Series- Counterflow Arrangement



— Unit 1 Heating - - - Unit 1 TH — Unit 2 Heating - - - Unit 2 TH  
— Series3 - - - Unit 1 TC — Series5 - - - Unit 2 TC

T Boiler In, °F	$\eta_{\text{Carnot.parallel}}$	$\eta_{\text{Carnot.series}}$	Relative
175	5.1%	8.4%	163.6%
200	9.1%	12.1%	133.2%
225	12.7%	15.5%	122.1%
250	16.0%	18.7%	116.3%
275	19.1%	21.6%	112.8%

**Net Efficiency Gain despite small increase in pump power!**

## Deployment Strategy:

If successful, the results of this R&D effort can easily be commercialized utilizing Johnson Controls' existing sales, project development, operations and maintenance organizations.

Research objectives are being met. No major obstacles anticipated for future development of prototype. Interconnection application submitted by OIT February 2012.

	FY2011	FY2012	FY2013
Target/Milestone	Go/No-Go Decision	Complete Final Design	Install Prototype
Results	Go decision in 2011	Completed in 2011	Scheduled for summer 2013

Timeline:

Planned Start Date	Planned End Date	Actual Start Date	Actual /Est. End Date
5/1/2010	5/1/2014	5/1/2010	12/1/2015

Budget:

Federal Share	Cost Share	Planned Expenses to Date	Actual Expenses to Date	Value of Work Completed to Date	Funding needed to Complete Work
\$1,047,000	\$1,093,000	\$2,059,634	\$1,979,634	\$1,979,634	\$80,000

Delay: Installation site at partner organization not yet ready. Two year data collection phase will start once the prototypes are put into service (Fall 2013).