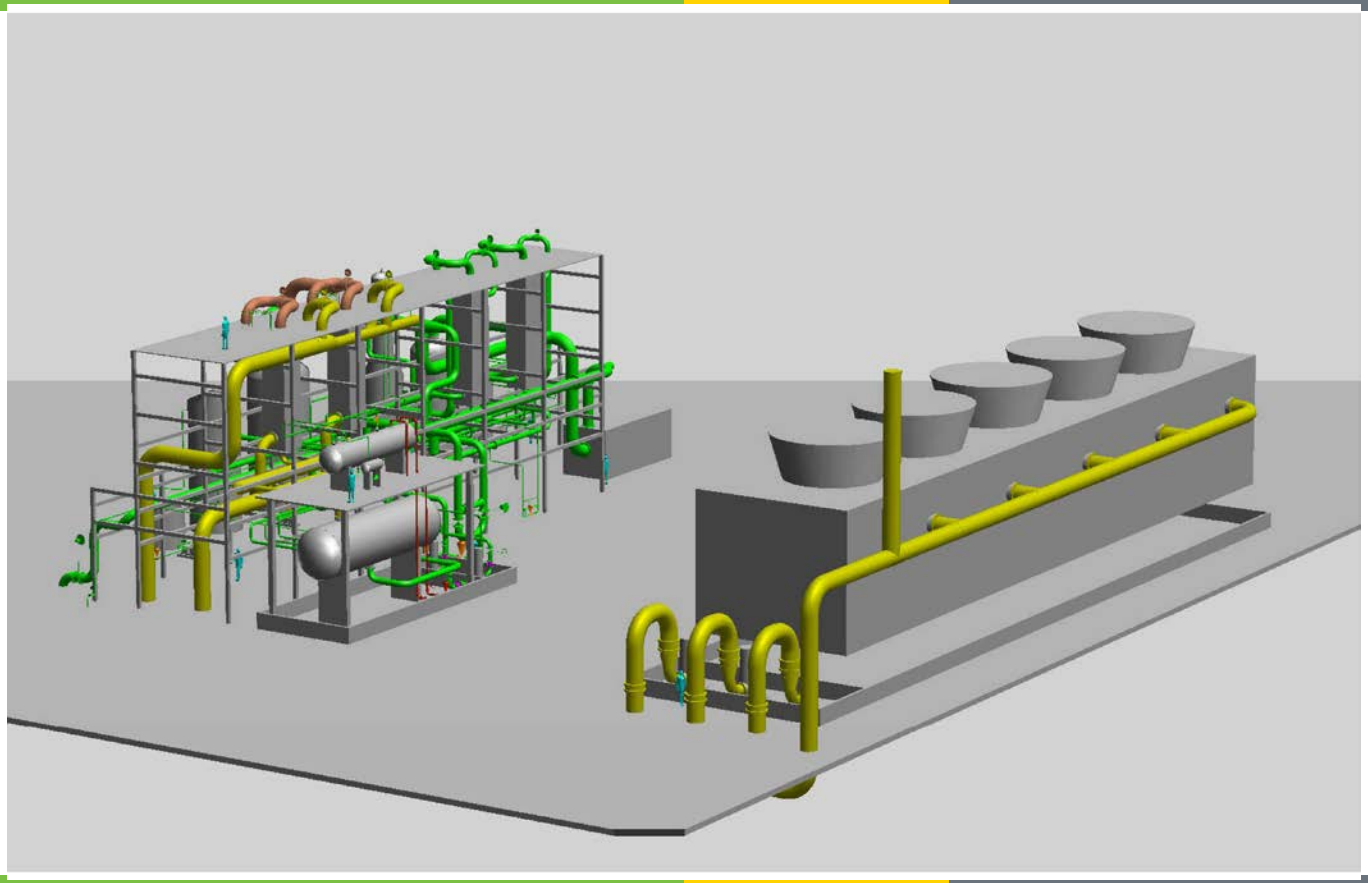


Kalex Advanced Low Temp Geothermal Power Cycle

Project Officer: Ava Coy

Total Project Funding: $2,000,000

April 22, 2013

Principal Investigator: Cheryl Sandifer

Presenter Name: Michael Mugerwa

Organization: Technip

Track Name: EGS, Low Temp and Co-Produced Demonstrations

Relevance/Impact of Research (1)

- Project Objective:
  - To validate the performance and economic advantages of an advanced ammonia-water mixed fluid cycle (‘Advanced Cycle’) during both on and off design point operating conditions in low temperature geothermal service

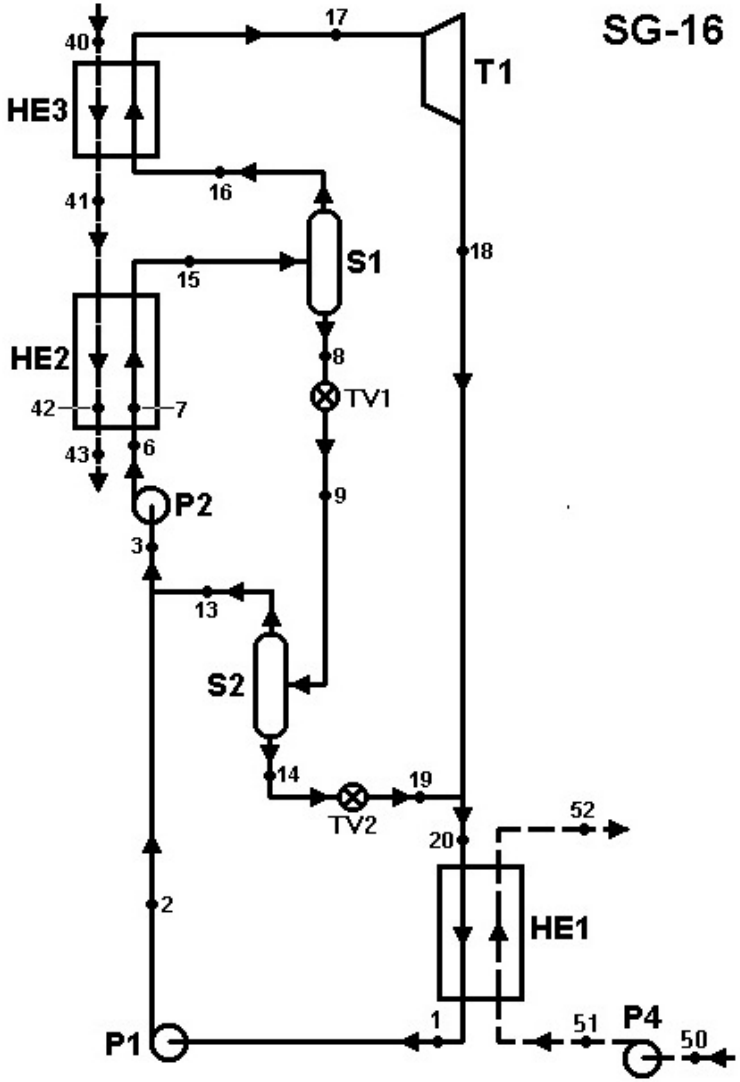
- Challenges, barriers, knowledge gaps or problems:
  - Severe performance penalties are incurred for projects using currently available technologies during off design point operation caused by cooler geothermal fluid temperatures
  - Low efficiencies for currently available geothermal technologies in low temperature applications often make new projects unviable, and increase project risk by increasing by the need for higher numbers of production wells
  - Early generation ammonia-water power cycles experienced significant service interruptions due to corrosion impacts following ingress of air in the working fluid, as well as leaking seals in plate / frame heat exchangers configurations
  - Low level heat input loads require significantly larger equipment, so crucially equipment must be value engineered to minimize costs / maximize performance

Relevance/Impact of Research (2)

- Innovation:
  - Advanced Cycle designs offer moderate to high efficiencies relative to current geothermal technologies in low temperature applications (190 – 220 deg. F)
  - Novel system design self-compensates for variations in geothermal working fluid temperatures, and diurnal / annual ambient temperatures changes
  - Significant cost / performance improvements over earlier generation ammonia-water power cycles
- Market Impact:
  - Advanced Cycle to demonstrate improved power generation levels for low temperature geofluid flows, requiring fewer and shallower geothermal production wells, reducing production field development costs and risks
  - Overall reduction in risk capital requirements leading to lower cost geothermal projects
- GTO Goal:
  - Increasing low-temperature geothermal capacity to 3GWe by 2020.
    - Placing an Advanced Cycle into low temperature geothermal service will provide a new viable alternative to existing technologies, increasing the number of commercially successful geothermal power plants

Additional Information

Kalex Advanced Cycle



Scientific/Technical Approach (1)

- Phase 1 Activities
  - Develop a structural conceptual model for the Lower Klamath Lake (LKL) geothermal area
  - Analyze flow test data from three existing wells in the LKL geothermal area to determine the Kalex plant design basis - geofluid flow rate & temperature
  - Develop and verify numerical simulation model of the Advanced Cycle to validate system performance at the expected geofluid temperatures of 200 deg. F and less.
  - Determine power plant performance considering annual and diurnal ambient temperature variations
  - Develop a process design package, followed by a total installed cost estimate
  - Complete Environmental Assessment in compliance with National Environmental Policy Act requirements for the LKL project
  - Initiate utility interconnect studies, and develop high voltage electrical infrastructure and transmission cost estimates

Scientific/Technical Approach (2)

- Phase 1 Activities
  - Respond to request for proposals for renewable Power Purchase Agreements (PPAs) from utilities in Oregon and California
  - Develop financial model for the demonstration project based on the Kalex Advanced Low Temperature Cycle to determine economic viability of the proposed LKL project in the current renewable power market. Perform sensitivity analyses based on project risk assessments
  - Review pre-agreed criteria < flow, temperature, power output, reservoir life, IRR > to facilitate the Go/No-Go/Redirect decision point onto Phase 2 activities
  - If the feasibility study results support continued development, begin development activities associated with design and construction of the Advanced Cycle demonstration project per Phase 2

Accomplishments, Results and Progress (1)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Complete Resource Viability Assessment for LKL Geothermal Area	Completed per plan	Q4 2011
Well 12C – Flow Testing, Temperature Profiling	Completed per plan	Q1 2012
Well 9A – Deepening, Flow Testing, Temperature Profiling	Drilling completed Q4 2012. Flow testing on hold.	
Grid System Impact Study	Completed per plan	Q4 2012
Environmental Assessment	Draft under review. Original plan called for Q4 2012 completion.	

Accomplishments, Results and Progress (2)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Advanced Cycle selection	Completed per plan	Q3 2012
Process Design Basis / Preliminary Cost Estimate	4.4 MWe gross plant capacity. Completed per plan	Q1 2013
Reliability, Availability, & Maintainability (RAM) Analysis	Completed per plan	Q1 2013

Future Directions (1)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Milestone or Go/No-Go	Status & Expected Completion Date
Value Engineering	Ongoing. Q2 2013
Definitive Cost Estimate	Ongoing. Q2 2013
Renewable PPA proposals	Ongoing. Q2 2013
Financial Modeling	Ongoing. Q2 2013
Phase 1 Go/No Go/Redirect	Decision expected Q2 2013 Targeting 9.6 MWe gross, single train.
Initial State Reservoir Model	Q2 2014
Demonstration Project EPC	Q1 2015
Commercial Operations / Data Collection	2015 - 2016

Future Directions (2)

- Key Challenges
  - High volume flows, low temperatures. The never ending quest for higher temperatures ….
  - Inverted temperature profiles in shallow wells
  - Geothermal licensing rights on USFWS lands
  - Value engineering to include critical equipment suppliers
  - Renewable PPA price downward trend. Have we hit rock bottom in 2013?
  - Lessons learned from existing plants in Iceland, Germany and Japan.

Summary

- Advanced Cycle designs offer various cost / performance options, the use of increased complexity is capacity dependent
- Value engineering must include critical equipment suppliers – heat exchangers, turboexpander generator, cooling tower
- Lessons learned to be incorporated from power plants performing both above and below expectations
- Lower project pricing to be achieved through standardized designs, supply chain developments, and competitive bidding for critical equipment
- With low temperature geofluids, the Advanced Cycle will outperform existing technologies yielding improved power generation levels, thereby reducing geothermal production well costs, and field development risks.
- At current low renewable PPA prices & Investment Tax Credit regime, the economics of a larger 9.6 MWe single train Kalex power plant holds promise
- Team to finalize Phase 1 activities and associated reports, and expects to reach the Go/No Go/Redirect decision milestone in Q2 2013.

Project Management

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Timeline:

Planned Start Date	Planned End Date	Actual Start Date	Current End Date
2011	2014	2011	2016

Budget:

Federal Share	Cost Share	Planned Expenses to Date	Actual Expenses to Date	Value of Work Completed to Date	Funding needed to Complete Work
$1,749,484	$34,723,114	$640,000	$398,000		$36,074,598

- Grant award novated from Oski Energy to Technip USA on 10/30/2012
- Project funding sources: Entiv Organic Energy, Technip, US DOE
- Technip manages Mannvit consultancy, engineering, vendors, constructors
- Entiv manages grid interconnect, NEPA compliance, drilling, consultants
- Economic studies indicate that the larger 9.6 MWe power plant holds promise. As such, the team is developing a backup site location in Klamath Hills where significantly higher geofluid flows exist
- The Lower Klamath Lake project will likely be slowed for 12 – 24 months pending more favorable PPA pricing / project economics