Dish Stirling High Performance Thermal Storage

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PROJECT OBJECTIVES

Goal:

- Demonstrate the feasibility of significant thermal storage for dish Stirling systems to leverage their existing high performance to greater capacity
- Demonstrate key components of a latent storage and transport system enabling on-dish storage with low exergy losses
- Provide a technology path to a 25kW$_e$ system with 6 hours of storage

Innovation:

- Leverage high performance heat pipes to support feasible system layout
- Develop and test high temperature, high performance PCM storage
- Optimize storage configuration for cost and exergy performance
- Latent storage *and* transport matches Stirling cycle isothermal input[1]

Q1 Milestones:

- Identify at least 1 salt and 2 metallic PCM's for in-depth evaluation and sample testing

[1]Andraka, C.E., Rawlinson, K.S., Siegel, N.P., "Technical Feasibility of Storage on Large Dish Stirling Systems," Sandia report SAND2012-8352 (2012).

APPROACH

- PCM development
  - Literature searches and modeling to develop candidate eutectics
  - Sample fabrication and characterization to develop properties
  - Modeling of compatibility with potential containment
  - Long-term testing of compatibility
- Storage optimization
  - Advanced modeling of PCM/heat pipe interfaces including free convection in combined solid/liquid states
  - Exergy and cost optimization
  - 2-D and 3-D models
- Proof-of-concept hardware subscale demonstration

[3] Shabgard, H., Faghri, A., Numerical Simulation of Latent Heat Thermal Energy Storage (LHTES) Systems for Solar Steam Generation Applications, to be submitted to peer-reviewed journal (2013).
[4] Shabgard, H., Robak, C.W., Bergman, T.L., Faghri, A., "Heat transfer and exergy analysis of cascaded latent heat storage with gravity-assisted heat pipes for concentrating solar power applications," Solar Energy 86 (3) (2012) 816–830.

Q1 KEY RESULTS AND OUTCOMES

- Contract negotiated and placed with UCONN for advanced 2-phase PCM modeling based on past publications
- Basic PCM heat transfer 2-D models built and tested to explore applicability of several 2-D representations
- Potential salt and metallic eutectic PCM's identified through FactSage models and literature searches, melting point as primary screening

System			Weight Percent			T_m [°C]	ΔH_m [J/g]	Mass for 400kWh (kg)	Volume 400kWh (m³)
A	B	C	A	B	C				
KCl						771	353	4079	2.67
NaCl						801	482	2988	1.92
CaF_2	LiF		44.6	55.4		767	780	1846	0.85
$CaCl_2$	KCl	($KCaCl_3$	59.82	40.18		748	246	5854	3.23
CaF_2	KF		18.89	81.11		782	405	3556	1.72
MgF_2	KF		13.42	86.58		783	501	2874	1.42
NaF	ZrF_4*		51.7	48.3		755	-		
KF	AlF_3	ZrF_4*	71.67	3.35	24.98	750			
Ca	Si		97.25	2.75		785	309	4660	3.33
Cu	Si		82.97	17.03		802	267	5393	0.89
Al	Cu	Si	2.35	82.55	15.1	763	258	5581	0.92
Cu	Mg	Si	50.25	24.51	25.22	742	548	2628	0.82
Mg	Si	Zn	48.25	37.84	13.91	FactSage does not show any			
Al	Cu	Mg	7.46	84.88	7.67	775	216	6667	1.20
$Li_{4.7}Si_2$						752	-		
$Li_{13}Si_4$						755	-		
Li_2Sn_5						793	-		
$MgCu_2$						797	276	5217	

NEXT QUARTER

- Downselect PCM candidates
  - manufacture samples for characterization
  - Start thermal properties, conductivity for optimization
  - Start HSC thermochemistry evaluation to determine cost-effective containment
  - Manufacture as many samples as possible to maximize successful final selection
- Continue to develop and validate 2-D PCM model
  - Improve 2-D configuration fidelity to 3-D actual cases
  - Add natural convection enhancement of heat transfer
  - Realistic boundary conditions and transient modes
- Heat pipe wick fabrication (FY12 funds)