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Dish Stirling High Performance Thermal Storage

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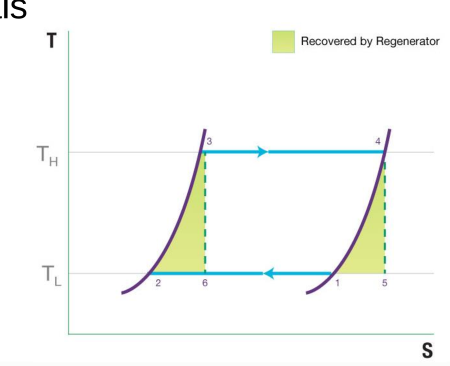
LPDP

CONCENTRATING SOLAR POWER

Introduction & Background

Concept

Enhancing high-performance dish-Stirling systems with up to 6 ours of thermal energy storage has the potential to increase performance, improve capacity, and enhance interest, making dish-Stirling systems a leading candidate to meet SunShot goals

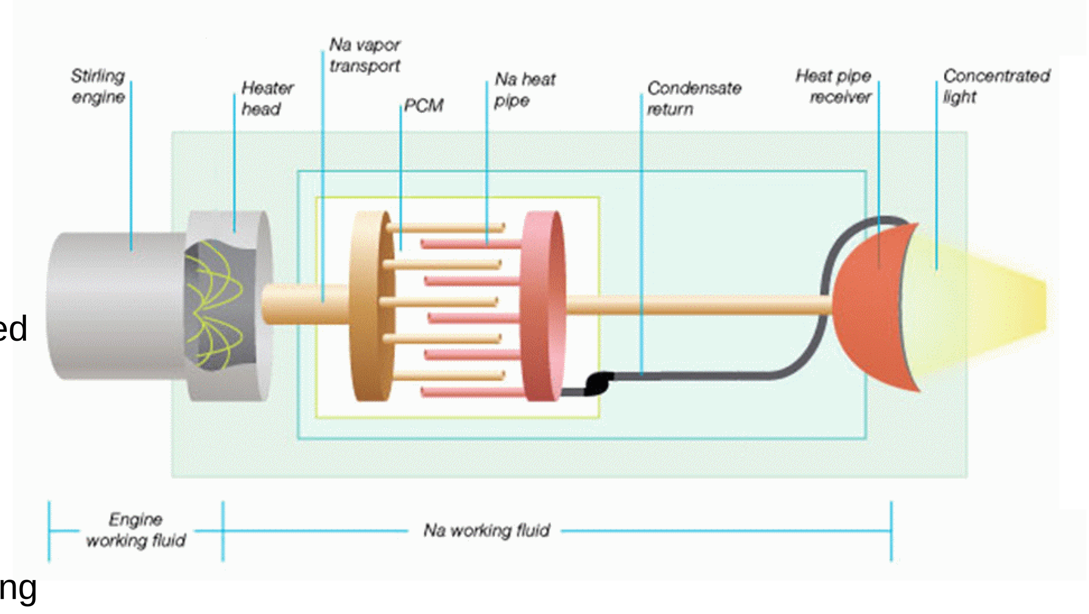


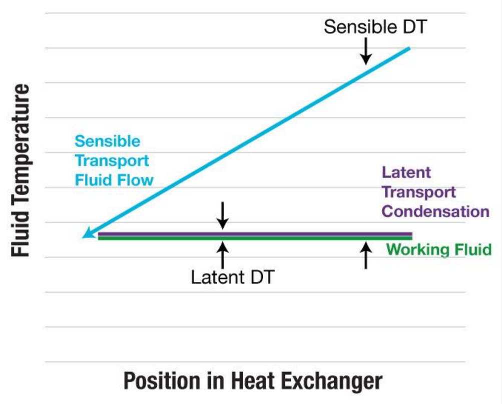
Why dish-Stirling?

- Demonstrated over 31% sun-to-grid, 26% annual
- High temperature, high concentration systems
- Highest efficiency thermodynamic cycle
- 6¢-8¢/kWh attainable with engineering and supply chain

Latent heat transport and storage

- Isothermal input to engine
- Best match to isothermal transport, isothermal storage
- High exergy efficiency
- Isothermal transport has additional demonstrated system performance improvements
- 10-20% system performance boost
- Independent optimization of receiver, storage, engine
- Heat pipe is a "thermal transformer"
- First- and second-law improvements over existing systems





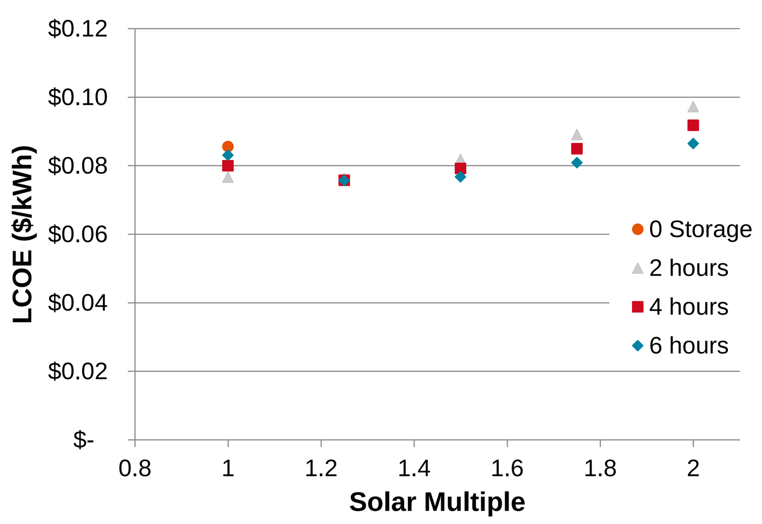
System Level Model

Field-level model

- Dish-to-dish shading
- Annual meteorological data (15-minute)

Storage accumulator model

- Thermal input from met data
- Thermal output when engine running
- Shed energy when full (lost)
- Measured data with heat pipe receiver



Clear financial benefit

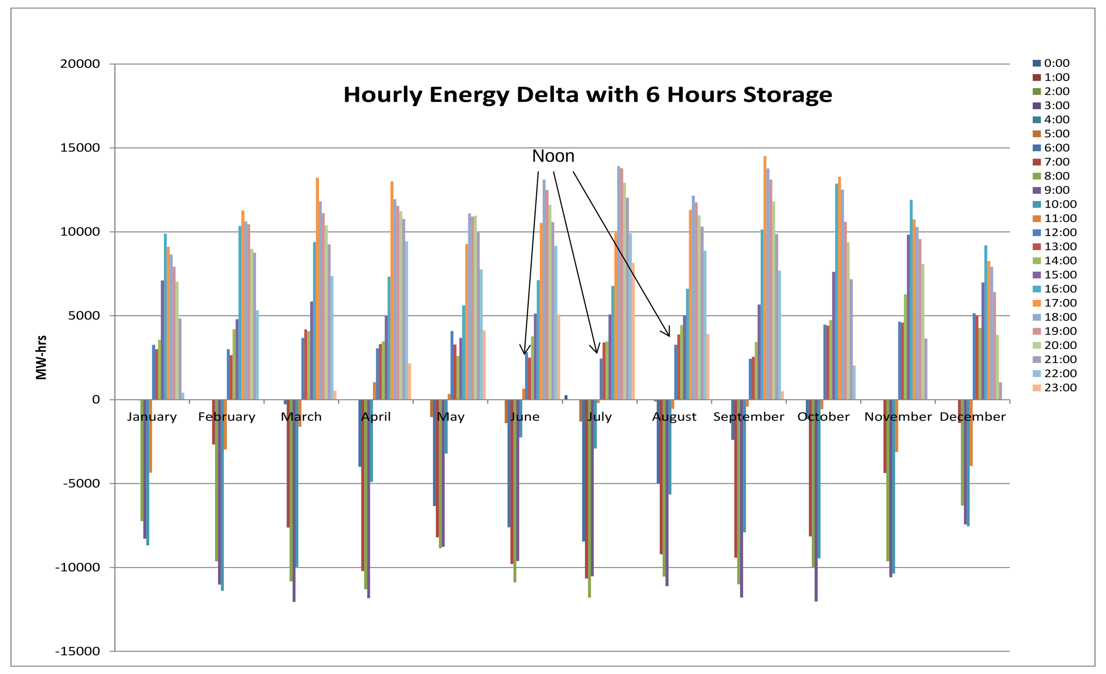
- About 1¢/kWh LCOE
- 2 ¢/kWh profit, due to TOD mapping

Clear optimum in Solar Multiple at 1.25 for cases studied

- Greater storage improves LCOE to a point
- Better amortization of equipment costs
- Too much storage cannot be consistently used

Financial model

- Calculate LCOE based on 7.42% FCR
- Calculate "profit" based on SCE TOD
- Adjust dish and spacing proportional to solar multiple
- Fixed and variable cost of storage
  - $3k/dish fixed
  - $20/kWh$_{th}$ variable with storage size
- System cost set to $2/W



Total energy increase

- Greater collection area (solar multiple)
- Higher efficiency (always at design point of engine)

Summer afternoon critical to profit

Model inputs exercised

- Size of storage
- Solar multiple
- Control modes

Substantial shift into evening hours

- Maximized lucrative summer PM hours
- Generation to midnight in summer

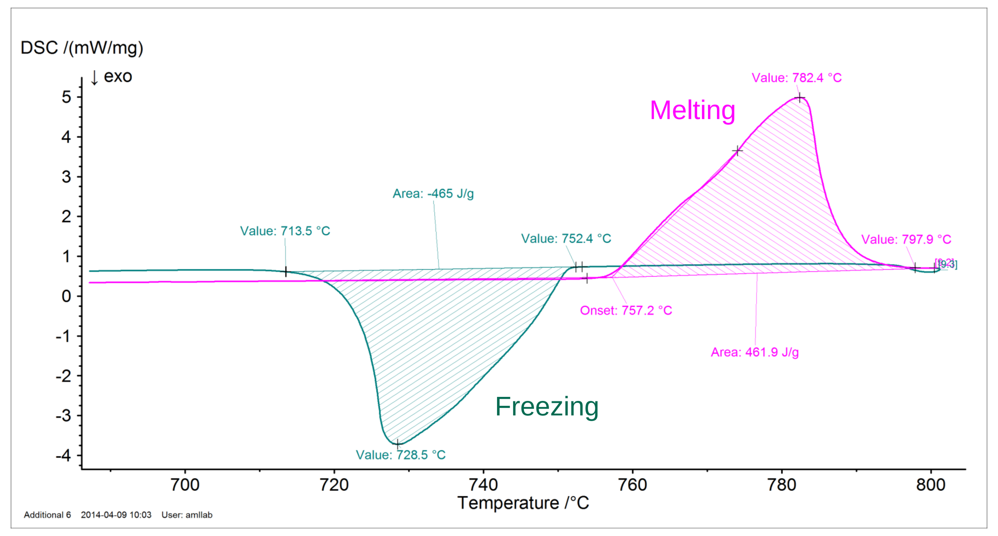
PCM Development and Compatibility

PCM Development and Selection

- Melting point goal 750-800°C
- Rough cost estimated
  - Heat of Melting
  - Cost of constituents
  - Goal under $40/kWh
- Metallic PCM's have suitable conductivity
  - 2-D modeling
  - Compared to salt eutectics
- Two potential PCM's identified
  - Literature
  - FactSage models
  - Phase Diagrams

PCM Fabrication

- Literature compositions varied
- Large variations of melt points of constituents
- Volatility
- Air sensitivity
- Both PCM's successfully developed
- High heat of melting confirmed for ternary
  - 462 J/g
  - 757°C Onset of Melt
  - 10°C/min ramp rate in DSC

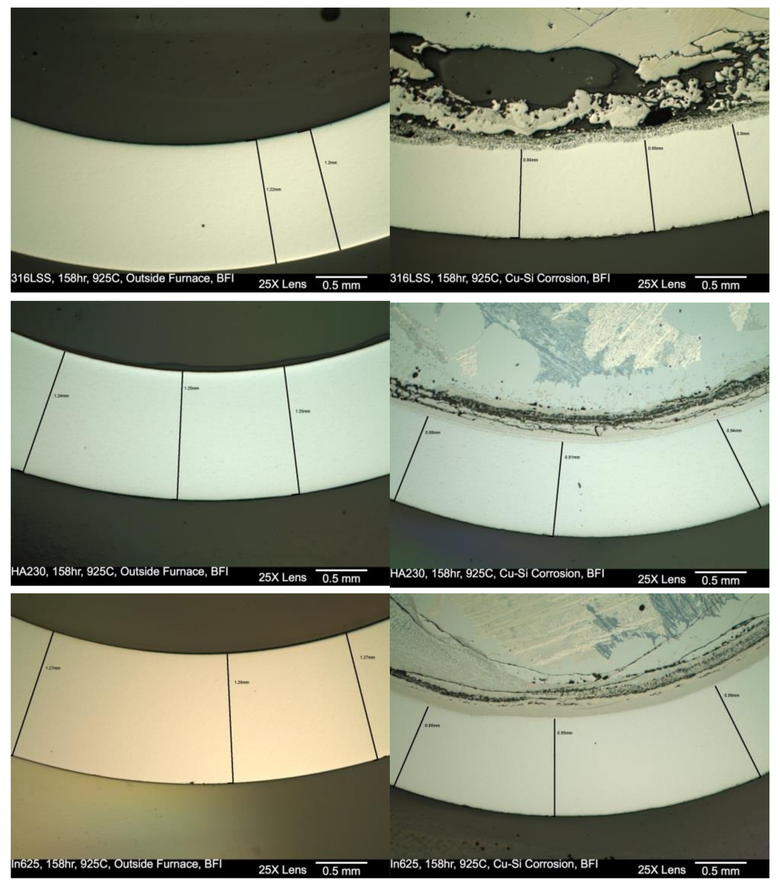


Ternary PCM Heat of Melting Characterization

PCM Compatibility

- Acute compatibility concerns raised
  - Ellingham diagrams
  - No kinetic information known
- Short-term J-tube test
  - Wall candidates based on sodium compatibility for heat pipes
  - J-tube test avoided weld and sealing issues
- Results
  - Three different wall materials
  - 30% wall loss in 150 hours
  - Differing mechanisms, same results
- Potential solutions
  - Alternative shell materials
  - Coatings
  - Alternative PCM's without Si
- Selected coatings as the most viable short-term solution

Acute compatibility J-tube



Containment Damage on 3 Materials

Summary and Future Work

Key findings

System Model

- Dish storage can improve LCOE and Profit
- Receiver and engine performance improves
- Full utilization of summer peaks
- Amortize system costs over more energy
- Storage size and solar multiple feasible
- Cloudy days are not overcome by storage
- Design and control strategies must account for profit, TOD pricing, capacity payments, and transmission requirements

PCM

- Two feasible metallic PCM's identified
- Containment corrosion an acute issue
- Coatings are the most feasible short-term solution

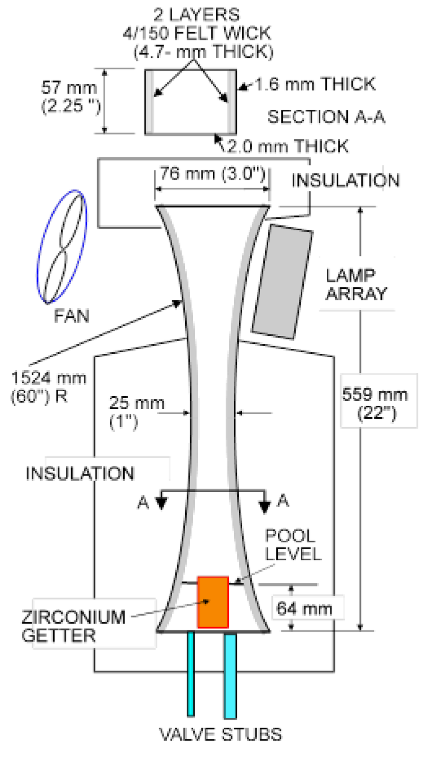
Path Forward

Coating Development

- Chemistry identification through Ellingham diagrams, equilibrium analysis, and literature
- Novel rapid screening of chemistry using pXRD technique
- Coating process development using geometry-constrained techniques
- Acute compatibility testing
- Long-term compatibility verification

System Demonstration

- Demonstration of key hardware components
  - High performance heat pipe wick durability
  - High conductivity PCM thermal storage
  - Materials compatibility and durability
- System-level end-to-end bench-top device



Bench-scale heat pipe durability test rig

SunShot U.S. Department of Energy

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