Using **Encapsulated Phase Change Material** for Thermal Energy Storage for Baseload CSP

Phase 2 Contract: DE-EE0003589
Start Date- July 2012
Expected End Date – Aug 2013

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Team Members

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Agenda

• Motivation for PCM storage
• Key Findings from Phase 1
• Encapsulation Methods
• Key Findings To date from Phase 2
• Next Steps
• Video
Motivation for Phase Change Material
Thermal Energy Storage (TES)

NOW

2 Years

5 Years

Two-Tank Sensible Heat TES, $30/kWht

TerraKline A Dual Media Managed Thermocline TES $20/kWht

TerraCaps Cascaded Encapsulated Phase Change TES $15/kWht
Technical Challenge / Solution
Encapsulated Phase Change TES

Challenge
When Salt Melts, Volume Increases. This Increase in Volume can Rupture the Shell

Solution TerraCaps.
Successfully Produced PCM Salt Capsules with Void to accommodate Change in Volume

Void for Expansion of Salt

Phase 1 Project Technology Breakthrough
Encapsulation Method 1

Sacrificial Material Concept for Creating Void

- Sacrificial polymer selected must completely decompose at low temperatures
Energy Density Cascaded PCM-TES

Improved Energy Density with Encapsulated PCM

52% improvement in Energy density with Cascaded Latent Heat Storage

Energy Density, kJ/kg

Temperature, deg C

Sensible only
Sensible+ Latent
A Cascaded Encapsulated PCM-TES

A 3-PCM Cascaded Encapsulated TES

Capsules Filled with Salts Melting at Progressively Higher Temperatures

TerraCaps Cascaded 3-PCM Encapsulated TES

Improves Energy Density by 35% to 50%
CSP with Cascaded Encapsulated PCM-TES

- Direct contact heat transfer with HTF
- 90% utilization of latent heat in salt capsules
PHASE 1 SUMMARY

• **Objective**
  Develop Economical Method to Encapsulate Nitrate Salt in Suitable Shell Material

• **Technical Barrier**
  Produce salt capsules with adequate void for salt to expand on heating

• **Key Results**
  Successfully developed a recipe to make 5mm capsules in lab
  Mathematical Model for Encapsulated TES
PHASE 2 OBJECTIVE

• Make Larger Capsules (~10mm)
• Optimize Recipe with small capsules
• Demonstrate Capsules are Robust
PHASE 2 MILESTONES

• Thermal cycling failure rate <0.1% per year
• Isothermal hold failure rate <0.1% per year
• FMEA of capsule breakage on HTF and TES system
• Optimize recipe
  ▪ minimize heat treatment time (<48 h heat treatment time)
  ▪ minimize expendable material
  ▪ Robust to material composition variations
• Cost of capsules <$5 per kWht
Repeat of Phase-1
Formulation – MOMs Recipe

- Formulation survives heating to >500°C
- Cross section shows salt
## Designed Experiments for Recipe Robustness

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*ICON = inorganic concentration*

*BCON = binder concentration*

*MIDDLE = middle layer thickness/mass %*

*OUTER = outer layer thickness/mass %*

Repeats to be added
Encapsulation Method 2

- Granules of Salt Pressed in Tablet Press
- Coated in a Pan Coater
- ~10 mm capsules undergoing thermal cycle tests
TerraDipper - Thermal Cycling Capsule Tester

Cold tank

Hot tank

Capsule trays

XZ Section thru the YZ Midline of the Hot Pot

YZ Section thru the XZ Midline of the Cold Pot

Functional Sketches 9-24-12
Thermal Cycling Capsule Tester

Capsule Trays

Test Rig Schematic
Capsule Integrity Measurements

- Optical Microscopy
- Differential Scanning Calorimetry
- Scanning Electron Microscopy
- Strength (Texture Analyzer)
Planned Activities Through August 2013

• Produce capsules and tablets with recipes using design experiments
• Conduct thermal cycling tests (> 5000 cycles), measure for integrity, calculate statistical failure rates
• Scale-up and manufacturing method
• Design TES System Test bed for Phase 3
Movie of Thermal Stability Capsule Tester
Thermal Cycling: Teradipper

- Process setup to expose capsules to thermal cycle
  - 250 °C to 430 °C
  - 5 minute cycle

Temperature of sample (dipper) probe.