Technology Advancements for Next Generation Falling Particle Receivers

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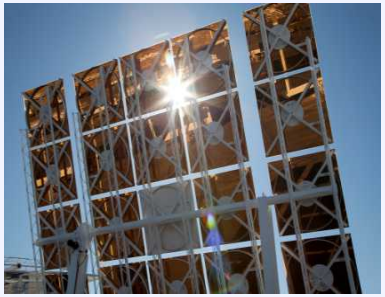
Exceptional service in the national interest

Sandia National Laboratories

Contributors:

- Sandia National Laboratories
- Georgia Institute of Technology
- Bucknell University
- King Saud University
- German Aerospace Center (DLR)



Clifford K. Ho

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U.S. DEPARTMENT OF ENERGY NNSA

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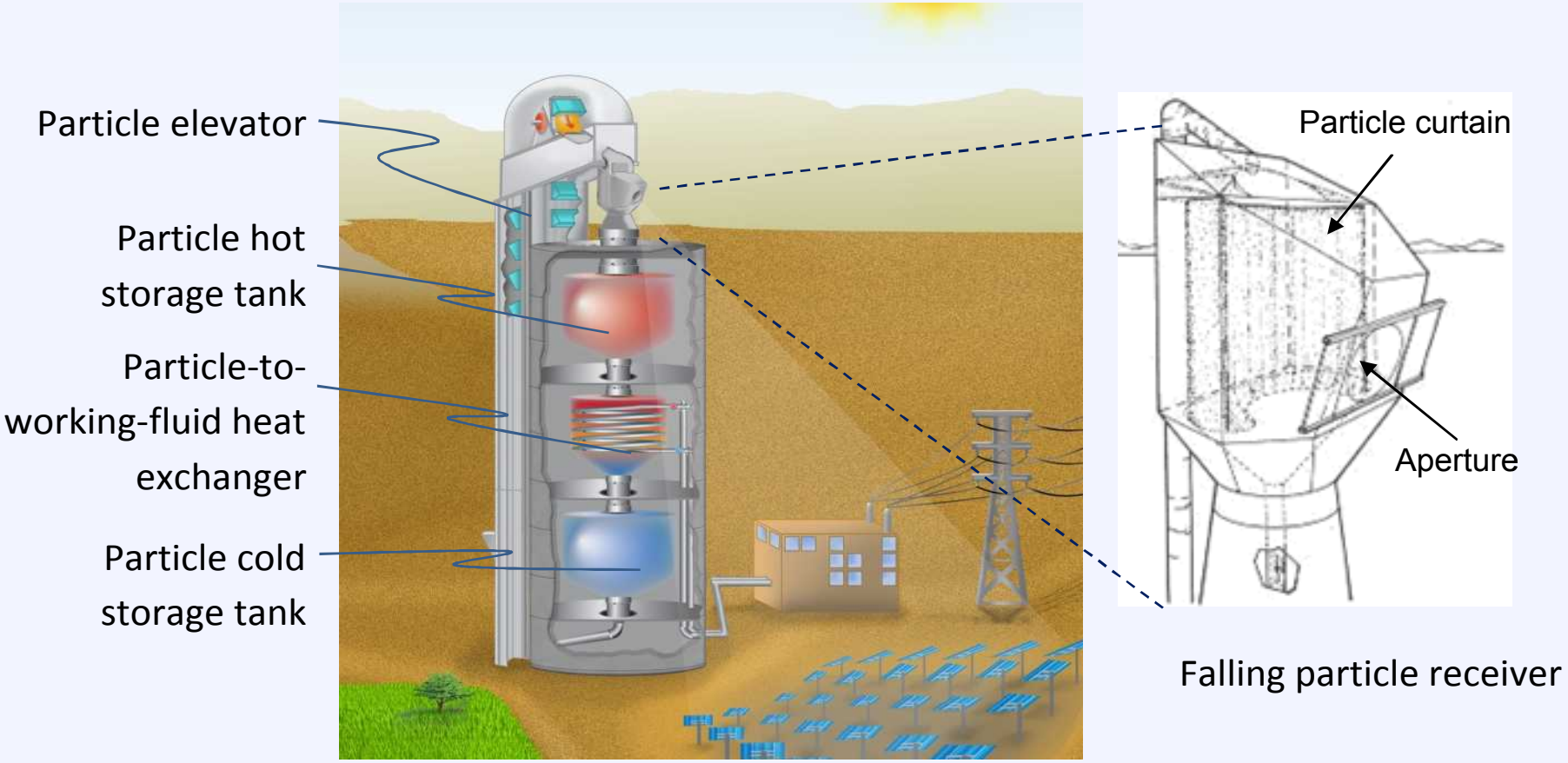
Technology Description



Falling Particle Receiver Technology

Presentation Overview

- Objectives
- Approach, Progress, and Results
  - Receiver
  - Particles
  - Balance of Plant
- Future Work

Project Objectives

- Make advancements in falling particle technologies that will enable higher temperatures and greater efficiencies at a lower cost
  1. Receiver designs
  2. Particle radiative properties and durability
  3. Balance of plant

Presentation Overview

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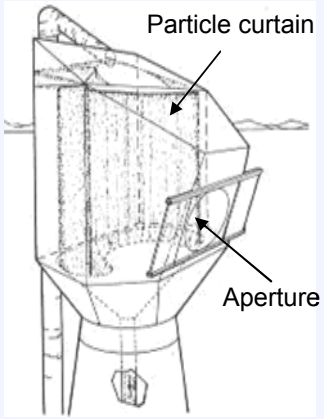
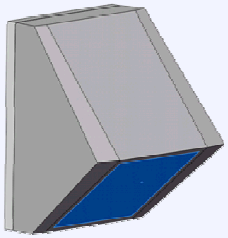
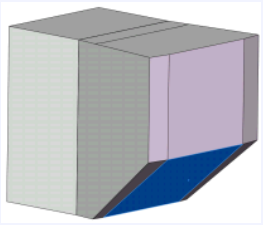
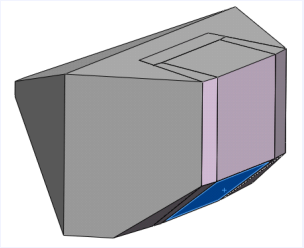
Receiver

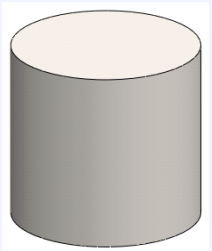


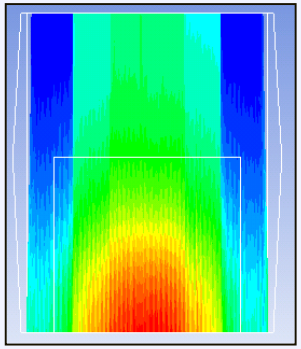
Particle Recirculation (SNL, DLR)

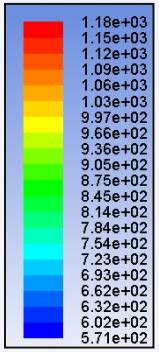




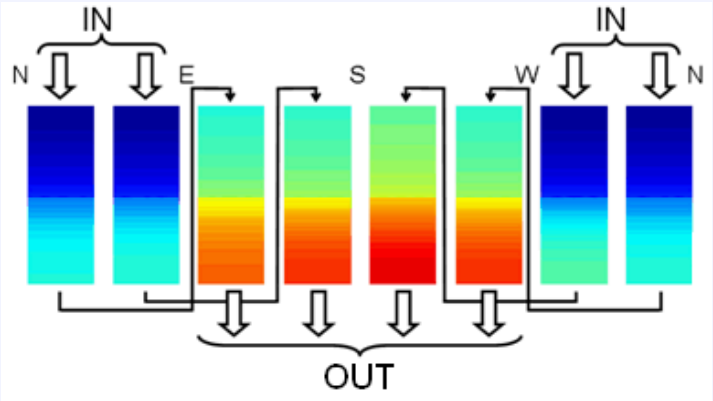








- Develop CFD models to evaluate and optimize receiver performance with varying recirculation designs
  - ANSYS FLUENT: Radiation, convection, discrete phase particles, turbulence
  - Two scales: 100 MW_e and prototype for testing

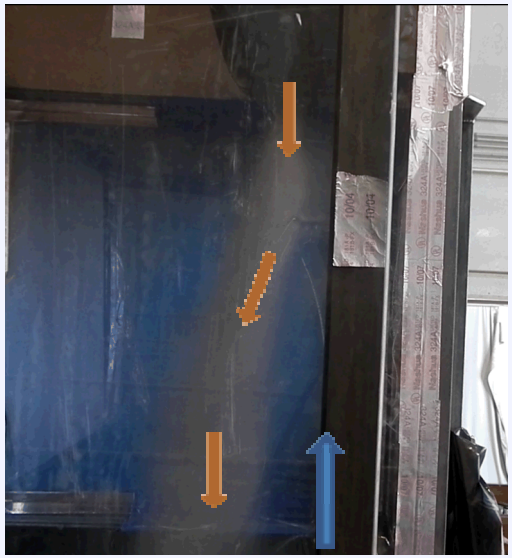


Christian and Ho, "Alternative Designs of a High Efficiency, North-Facing, Solid Particle Receiver," SolarPACES 2013; **Wed. poster**

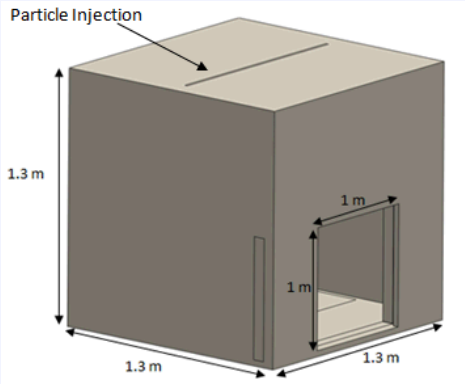
Prototype Receiver to Evaluate Particle Flow and Air Curtain

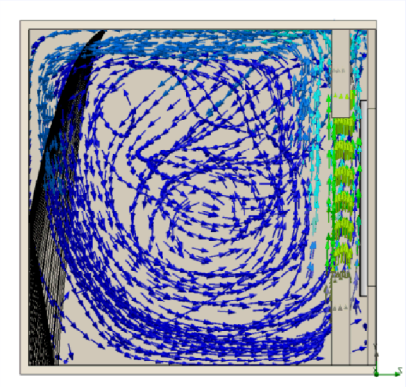
∴ Investigated particle size, particle flow rate, drop location, air flow rate, external wind

Air Curtain (SNL)

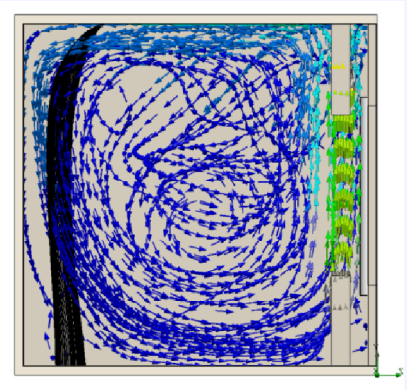


- Evaluate use of air recirculation in falling particle receiver to reduce heat loss and impacts of external wind
  - Investigate particle size, location, particle flow rate, air flow rate, external wind

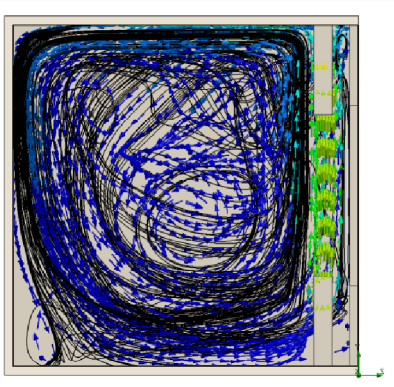




1 mm particle size

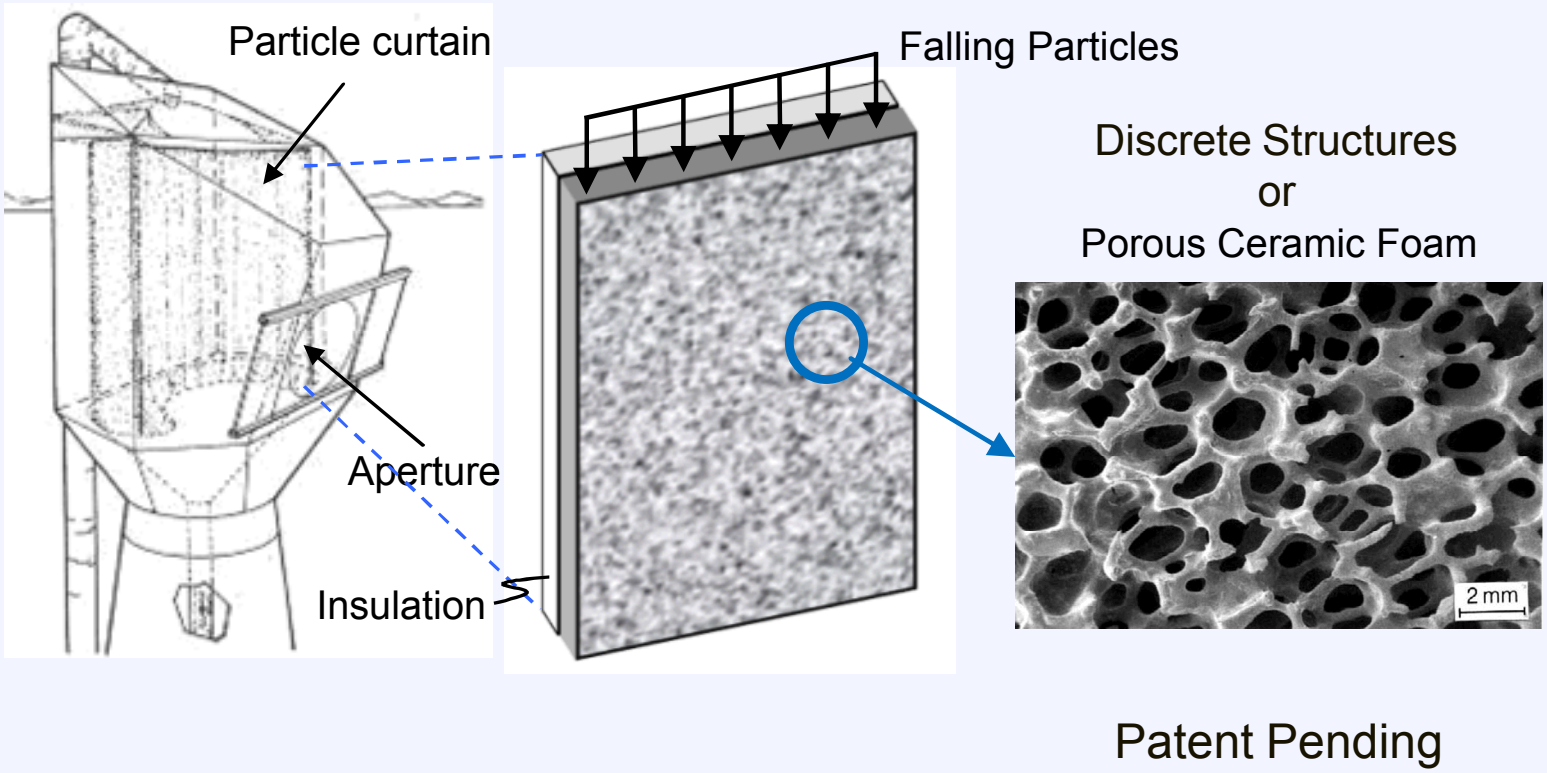


100 μm particle size



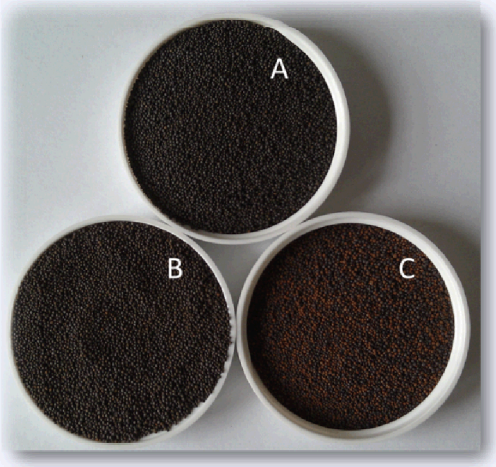
10 μm particle size

Discrete Porous Structures (Georgia Tech, KSU)



Patent Pending

Particles



Particle Radiative Properties (Bucknell, SNL)

Material Name	Type	Solar weighted absorptivity	Thermal emissivity*	Selective Absorber Efficiency**
Carbo HSP	Sintered Bauxite	0.934	0.843	0.864
CarboProp 40/70	Sintered Bauxite	0.929	0.803	0.862
CarboProp 30/60	Sintered Bauxite	0.894	0.752	0.831
Accucast ID50K	Sintered Bauxite	0.906	0.754	0.843
Accucast ID70K	Sintered Bauxite	0.909	0.789	0.843
Fracking Sand	Silica	0.55	0.715	0.490
Pyromark 2500	Commercial Paint	0.97	0.88	0.897

*Spectral directional reflectance values were measured at room temperature. The total hemispherical emissivity was calculated assuming a surface temperature of 700 °C.

**Q is assumed to be 6×10^5 W/m^2 and T is assumed to be 700 °C (973 K): $\eta_{sel} = \frac{\alpha_s Q - \varepsilon \sigma T^4}{Q}$

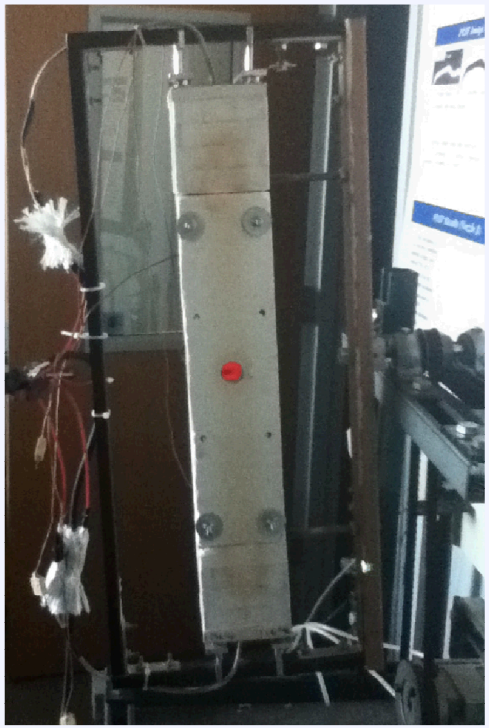
SunShot U.S. Department of Energy

Siegel et al., "Physical Properties of Solid Particle Thermal Energy Storage Media for CSP Applications," SolarPACES 2013; **Wed. 16:55**

Particle Durability (Georgia Tech, DLR, Sandia)

- Laboratory tests for surface impact evaluation, attrition, and sintering

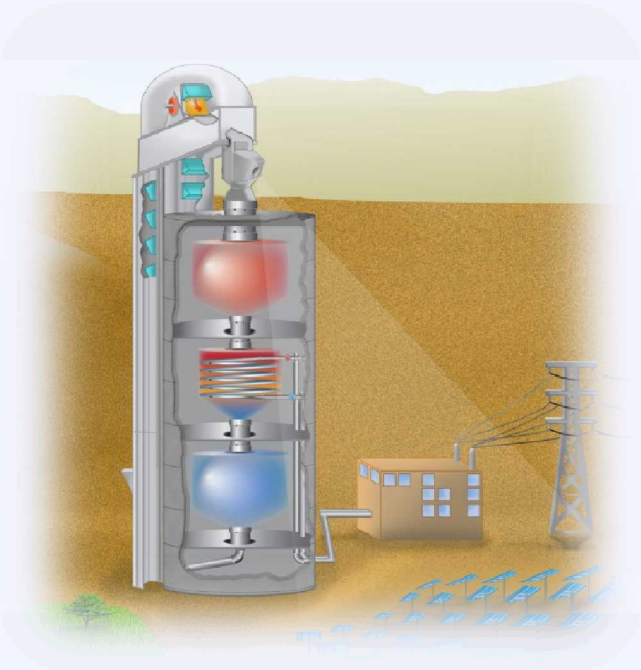
Ambient drop tests at ~10 m



Thousands of drop cycles at ambient and elevated temperatures (up to 1000 ˚C)

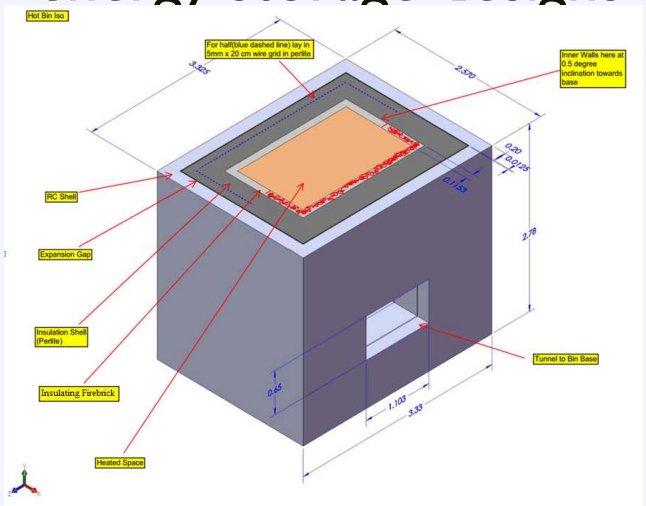
- Knott et al., "Examining the Effects of High Temperatures on the Durability of Solid Particles for Use in Thermal Energy Storage," SolarPACES 2013
- Al-Ansary et al., "Characterization and Sintering Potential of Solid Particles for Use in High Temperature Thermal Energy Storage System," SolarPACES 2013, **Thurs. Poster**

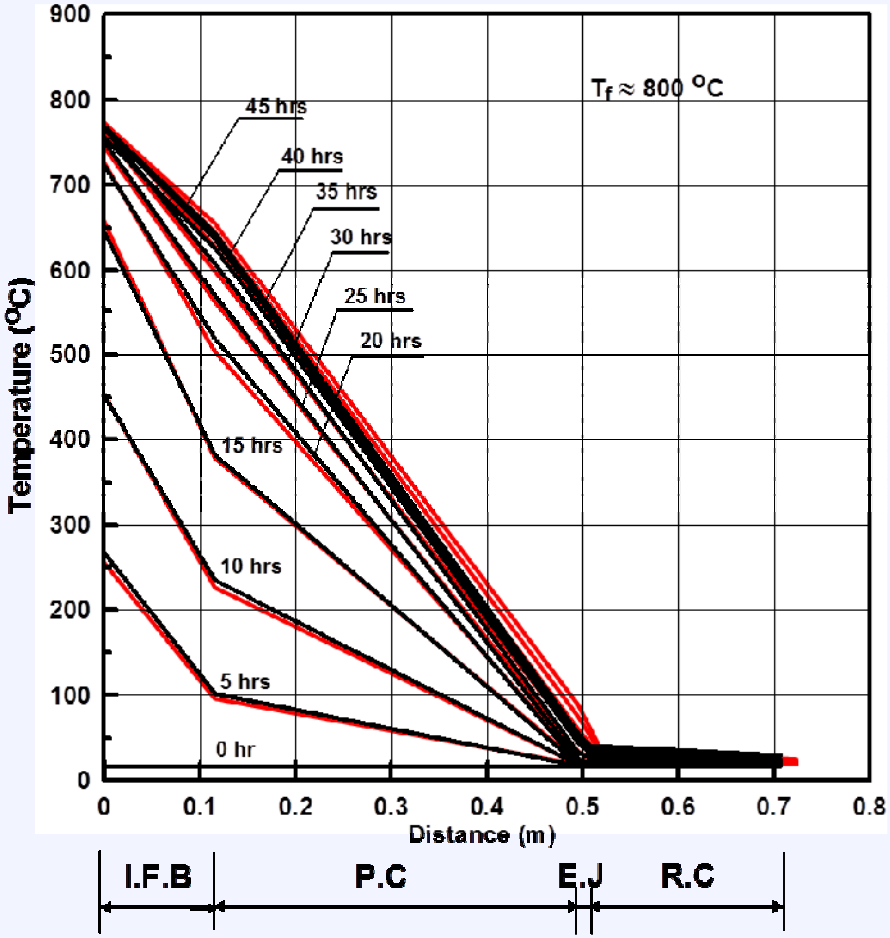
Balance of Plant



Thermal Storage (KSU and Georgia Tech)

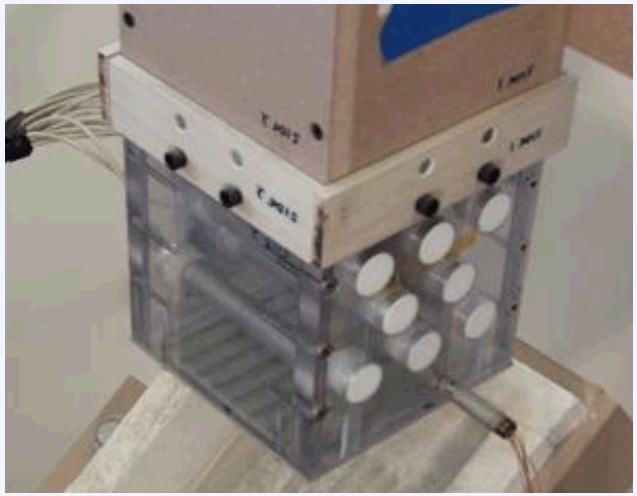
- Experimental evaluation and modeling of prototype thermal energy storage designs





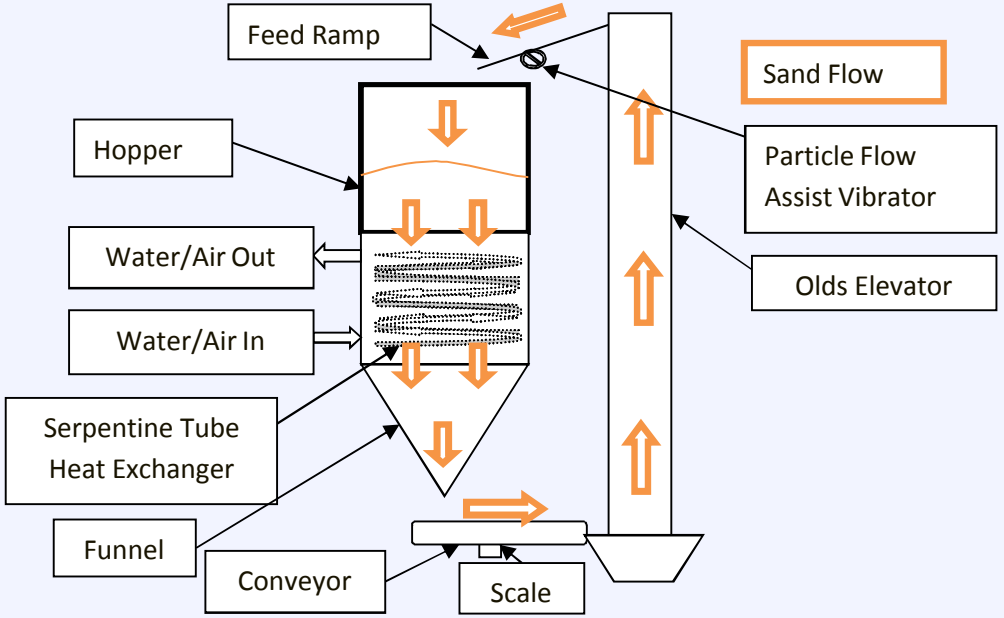
- El-Leathy et al., "Experimental Study of Heat Loss from a Thermal Energy Storage System for Use with a High-Temperature Falling Particle Receiver System," SolarPACES 2013, **Wed, 11:10**

Particle to Working Fluid Heat Exchanger (Georgia Tech)



Bench-scale heat exchanger

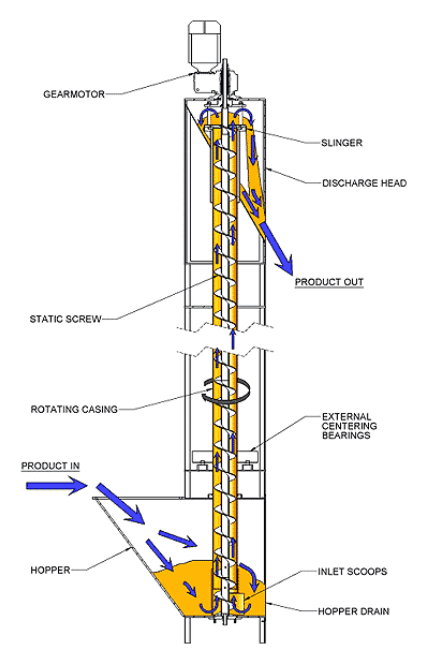
- Experimental evaluation of heat transfer coefficients & particle flow
  - Heat exchanger module designed and instrumented for continuous sand flow over heated tubes

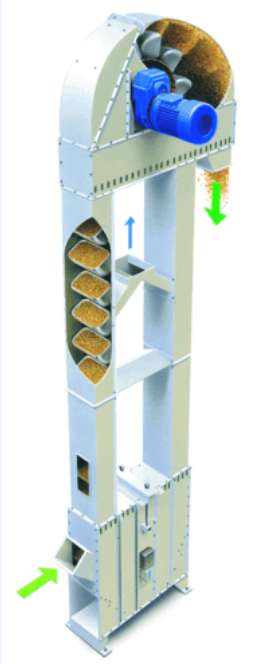


Full-scale heat exchanger

Golob et al., 2013, "Serpentine Particle-Flow Heat Exchanger with Working Fluid, for Solar Thermal Power Generation," SolarPACES 2013

Particle Lifts (GT, SNL, DLR)





- Evaluate commercial particle lift designs
  - Requirements
    - Up to 10 kg/s/m
    - Particle loss ≤ 0.01% of mass flow
    - Operating temperature ~ 500 °C (assumes ΔT during last drop of >200 °C)
  - Different lift strategies evaluated
    - Olds Elevator
    - Screw-type
    - Bucket
    - Mine hoist

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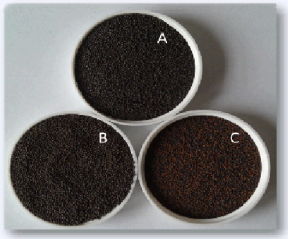
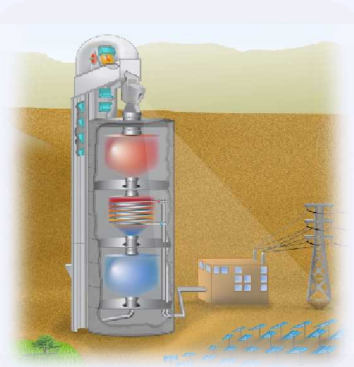
Future Work

- Receiver
  - Perform prototype testing to validate CFD models of particle flow and thermal efficiency
  - Evaluate reliability
- Particles
  - Evaluate long-term heating effects and chemical modification on radiative properties
- Balance of plant
  - Evaluate economics of storage, exchanger, and lift systems





Acknowledgments

SunShot U.S. Department of Energy

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- **Sandia National Labs**
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- **Bucknell University**
  - Nate Siegel, Michael Gross
- **King Saud University**
  - Hany Al-Ansary, Abdelrahman El-Leathy, Eldwin Djajadiwinata, Abdulaziz Alrished
- **DLR**
  - Lars Amsbeck, Reiner Buck, Birgit Gobereit

Questions?

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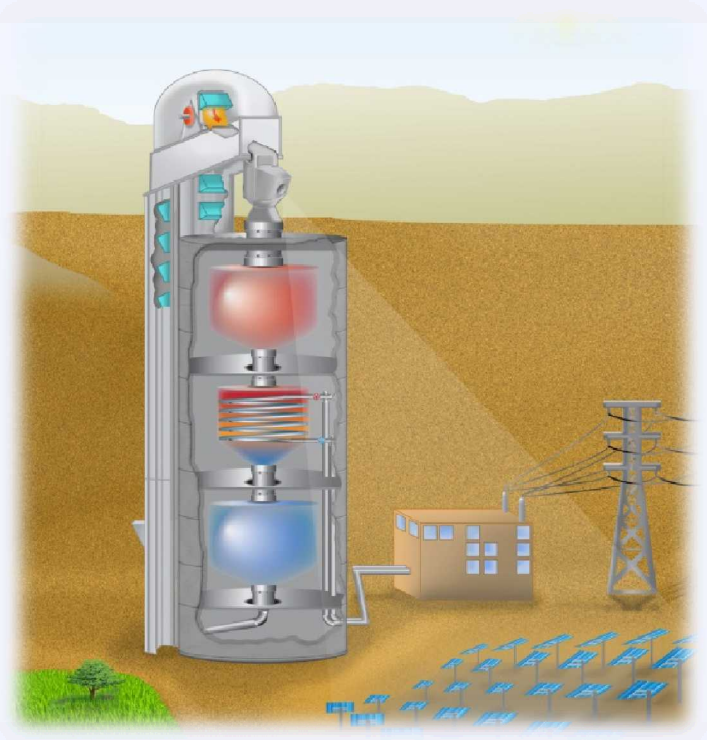

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