High Temperature Falling Particle Receiver

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Contributors:

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

Presenter: Clifford K. Ho, SNL

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NNSA National Nuclear Security Administration

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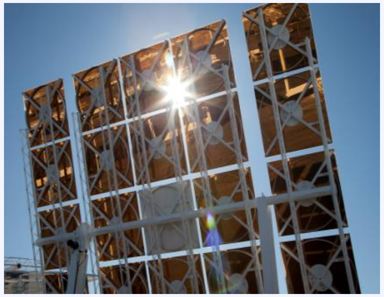
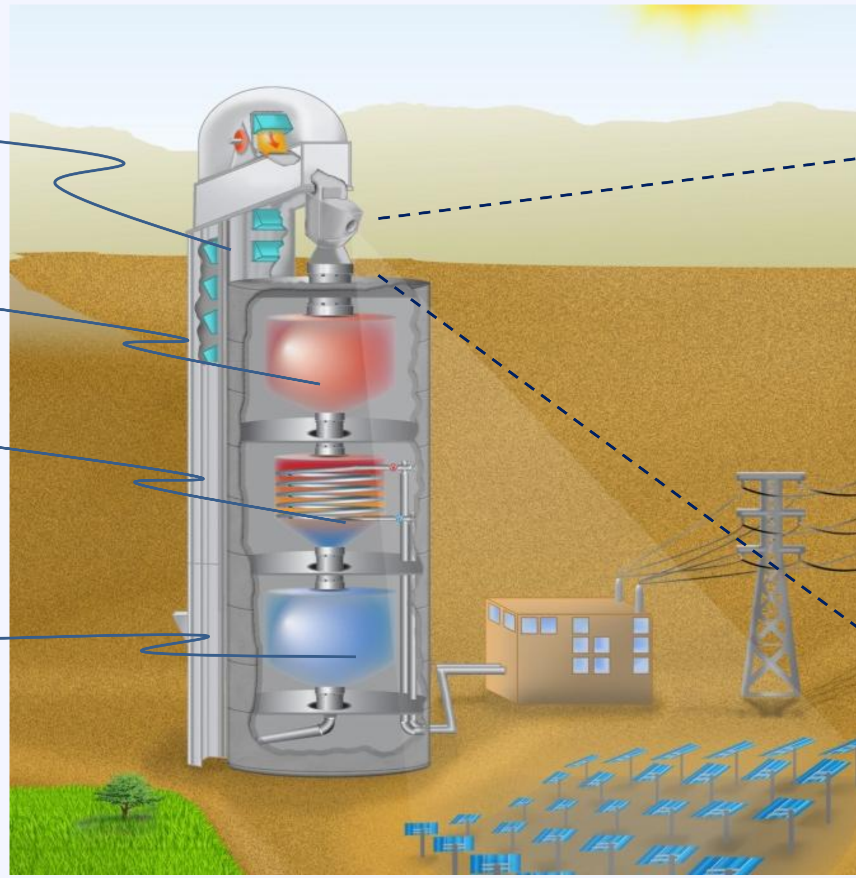
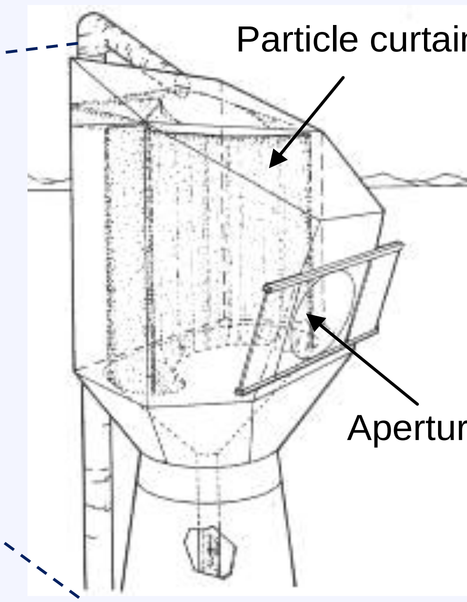


Technology Description





Falling particle receiver

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

Research Areas

Subsystem 1: Receiver	Subsystem 2: Particles	Subsystem 3: Balance of Plant
1.1 Particle Recirculation (SNL)	2.1 Particle Radiative Properties (B, SNL)	3.1 Thermal Storage (KSU, GT)
1.2 Air Recirculation (SNL)	2.2. Particle Durability (GT, DLR)	3.2 Heat Exchanger (GT)
1.3 Interconnected Porous Structures (GT, KSU)		3.3 Particle Tower Lift (GT, KSU, DLR, SNL, B)

SNL = Sandia National Laboratories, GT = Georgia Tech, B = Bucknell University, KSU = King Saud University, DLR = German Aerospace Center

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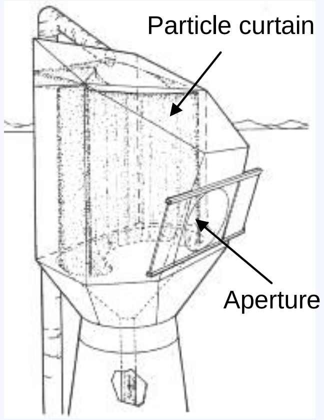
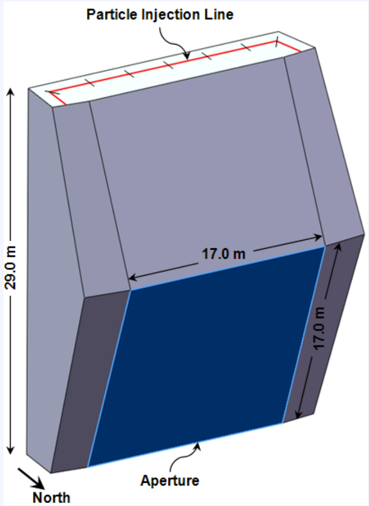
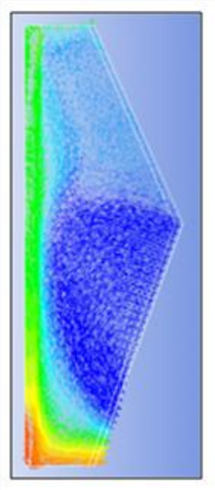
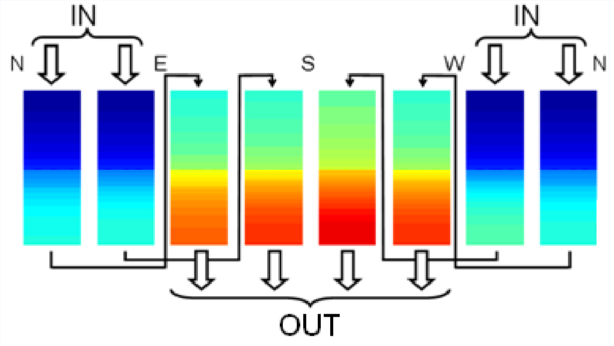
Receiver



Task 1.1 Particle Recirculation (SNL)

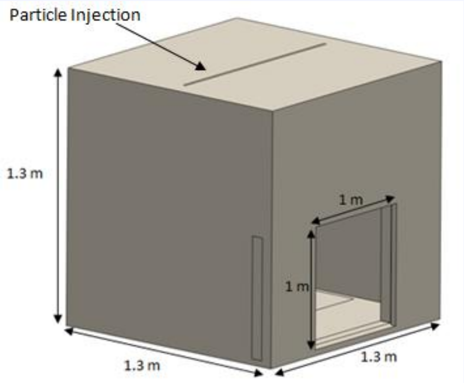




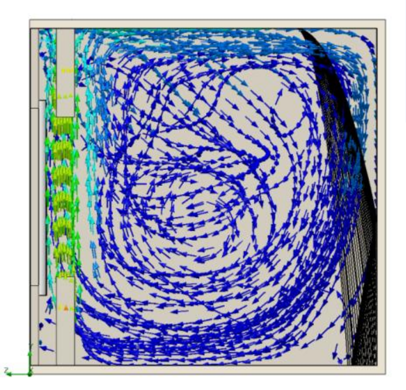


- Develop CFD models to evaluate and optimize receiver performance with varying recirculation designs
  – ANSYS FLUENT: Radiation, convection, discrete phase particles, turbulence
  – Two scales: 100 MW_e and prototype for testing
  – Investigate effects of aperture size, tilt, baffle, dimensions, air curtain

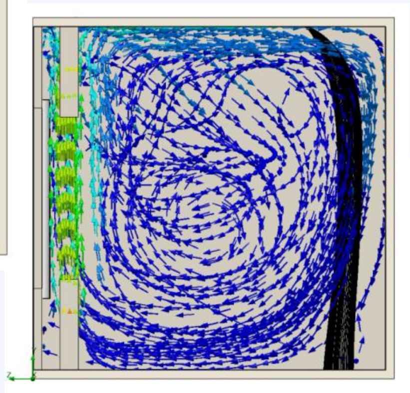
Task 1.2 Air Recirculation (SNL)



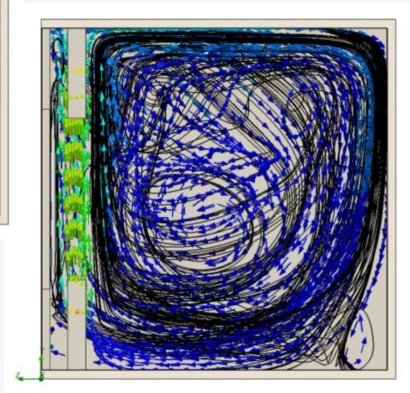
- Evaluate use of air recirculation in falling particle receiver to reduce heat loss and impacts of external wind
  - Prototype system constructed and modeled
  - Blower (bottom) and intake (top) for recirculation
  - CFD simulations show curtain stability impacted by particle size



1 mm particle size



100 μm particle size

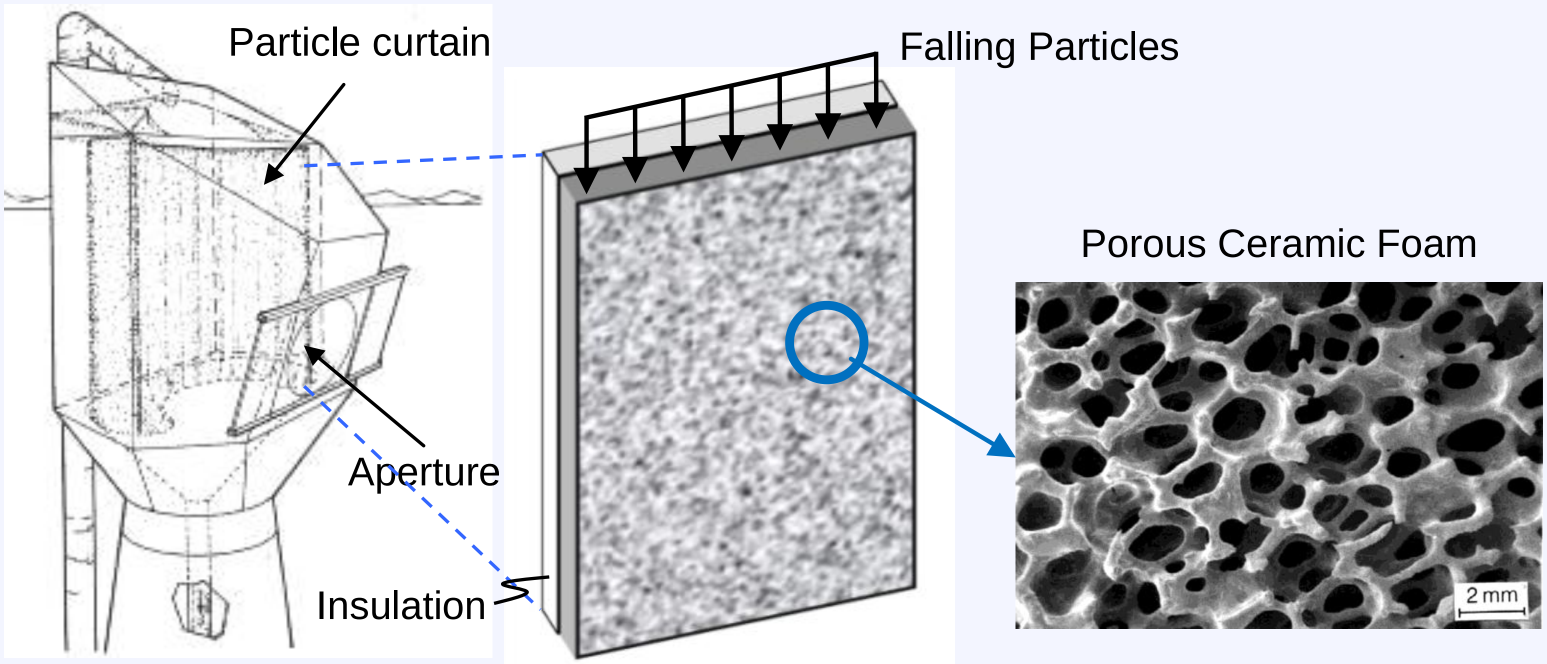


10 μm particle size

Prototype Receiver

∴ Current results show good particle stability with air curtain

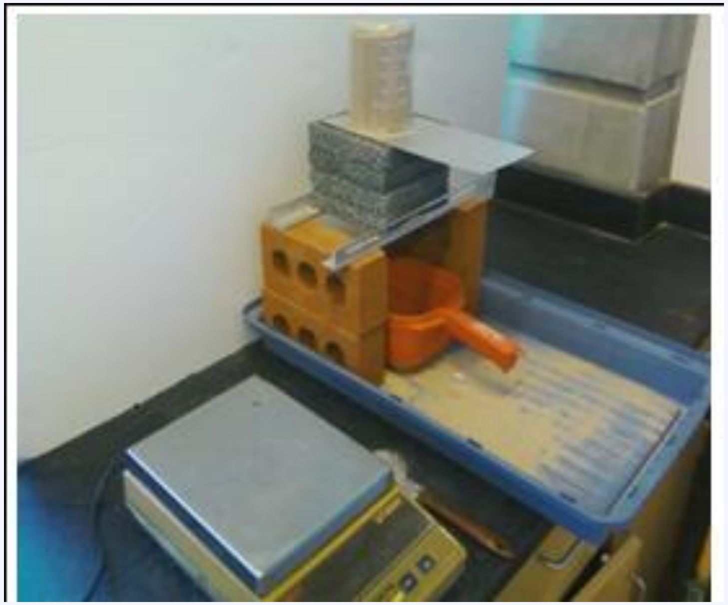
Task 1.3 Interconnected Porous Structures (Georgia Tech, KSU)

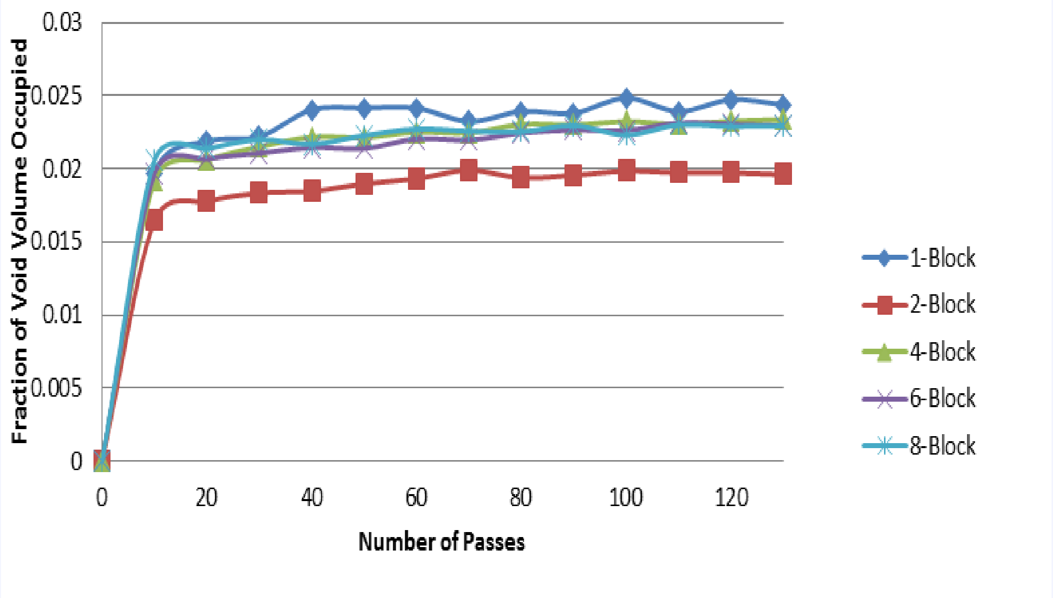


Patent Pending

Task 1.3 Interconnected Porous Structures (Georgia Tech, KSU)

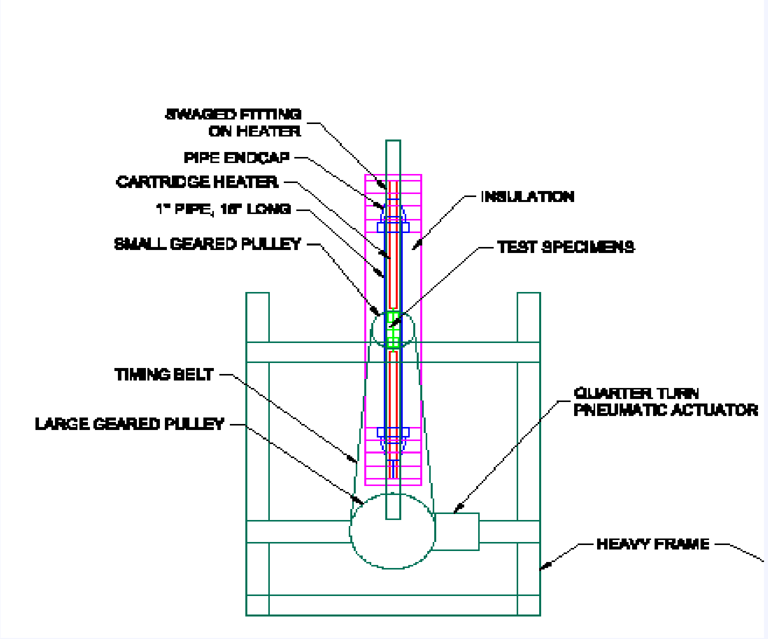
- Lab-scale evaluation of flow characteristics in ceramic porous structures
  - Measure the amount of sand accumulated in horizontally-stacked porous Silicon Carbide Ceramic blocks
  - Two, four, six and eight square-faced porous blocks were stacked
  - 100 mesh (~150 micron) fracking sand poured over blocks and weight measured after each set of 10 passes

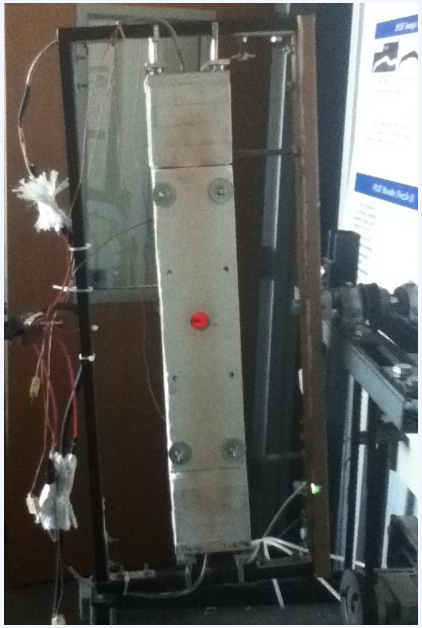




Task 1.3 Interconnected Porous Structures (Georgia Tech, KSU)

- Lab-scale evaluation of porous structure thermal performance
  - Hourglass-like apparatus designed to test flow of particles through porous specimen in middle at elevated temperatures (up to 1000 C)
  - Apparatus rotated half-turn on timed intervals for many cycles
  - All components procured and construction has begun





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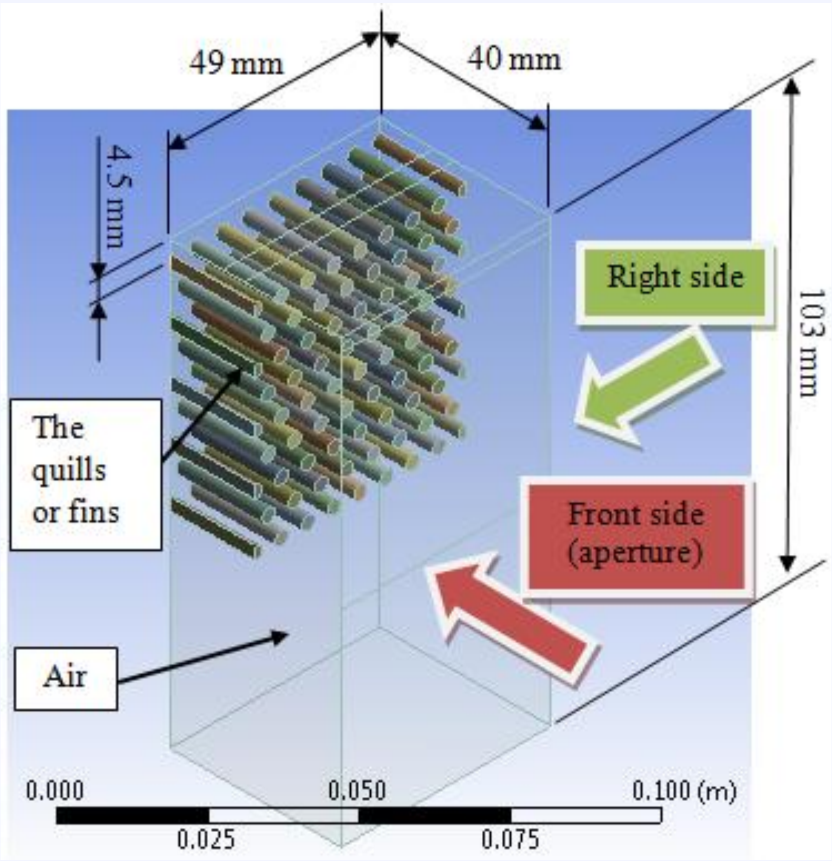
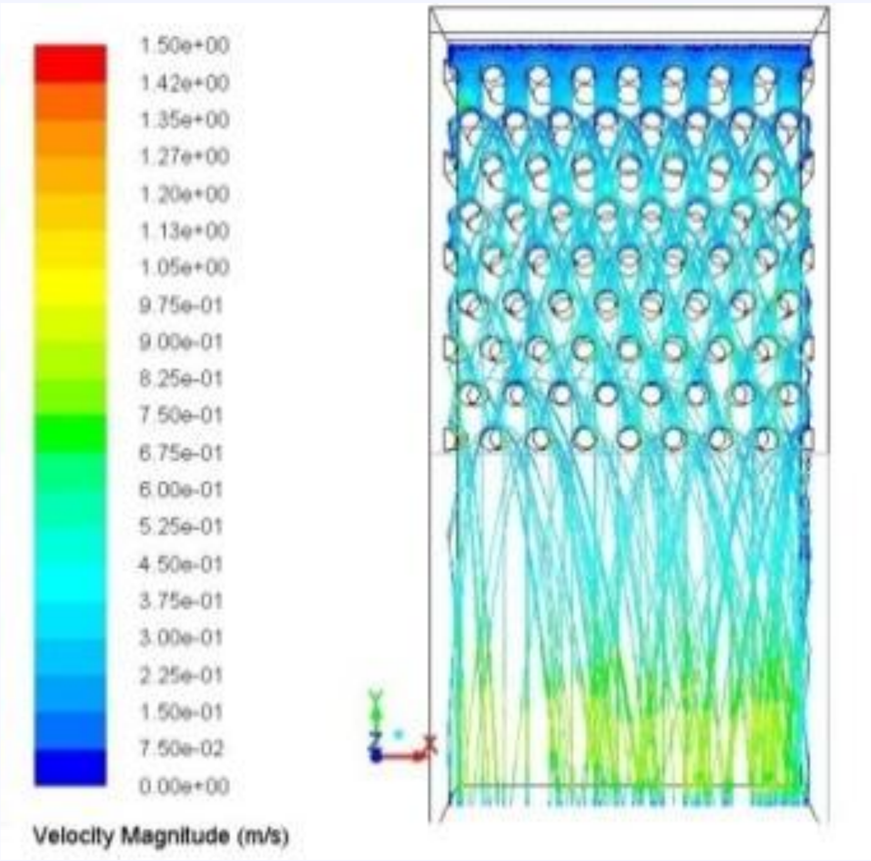
Task 1.3 Interconnected Porous Structures (Georgia Tech, KSU)





Patent Pending

Evaluation of “porcupine” structure with quills to impede particle flow

Particles

Task 2.1: 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): $\eta_{sel} = \frac{\alpha_s Q - \varepsilon\sigma T^4}{Q}$

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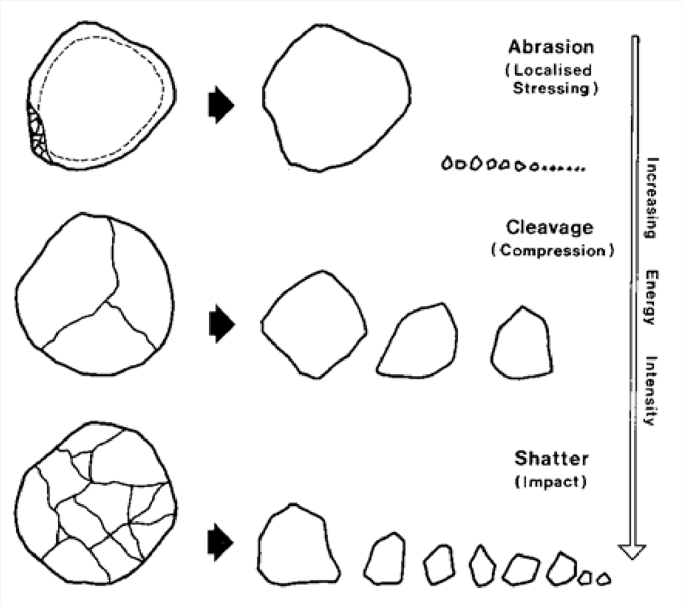
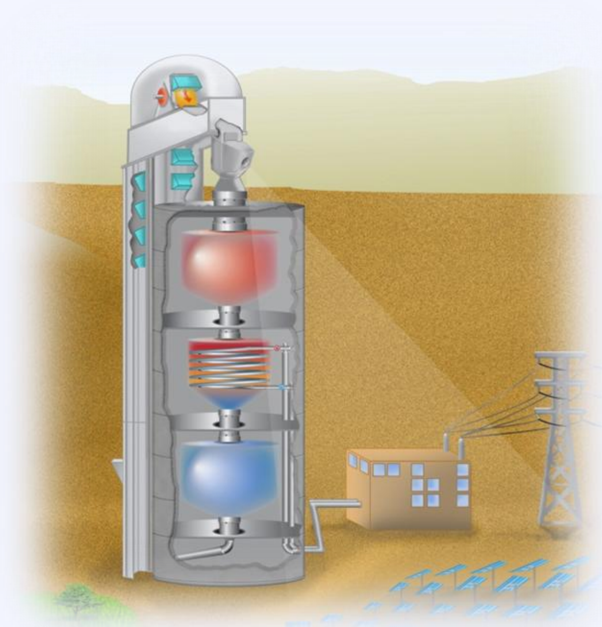
Task 2.2 Particle Durability (Georgia Tech, DLR)

0.5 m　　1.72m　　10 m drop devices

- Design and construction of laboratory test for surface impact evaluation
  - Evaluated attrition mechanisms
    - Abrasion is primary mode for our case
  - Devices for three drop heights were constructed (0.5, 1.72, and 10 m)

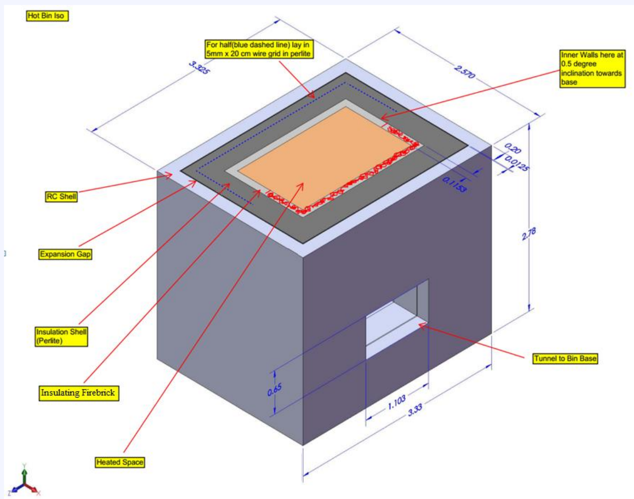


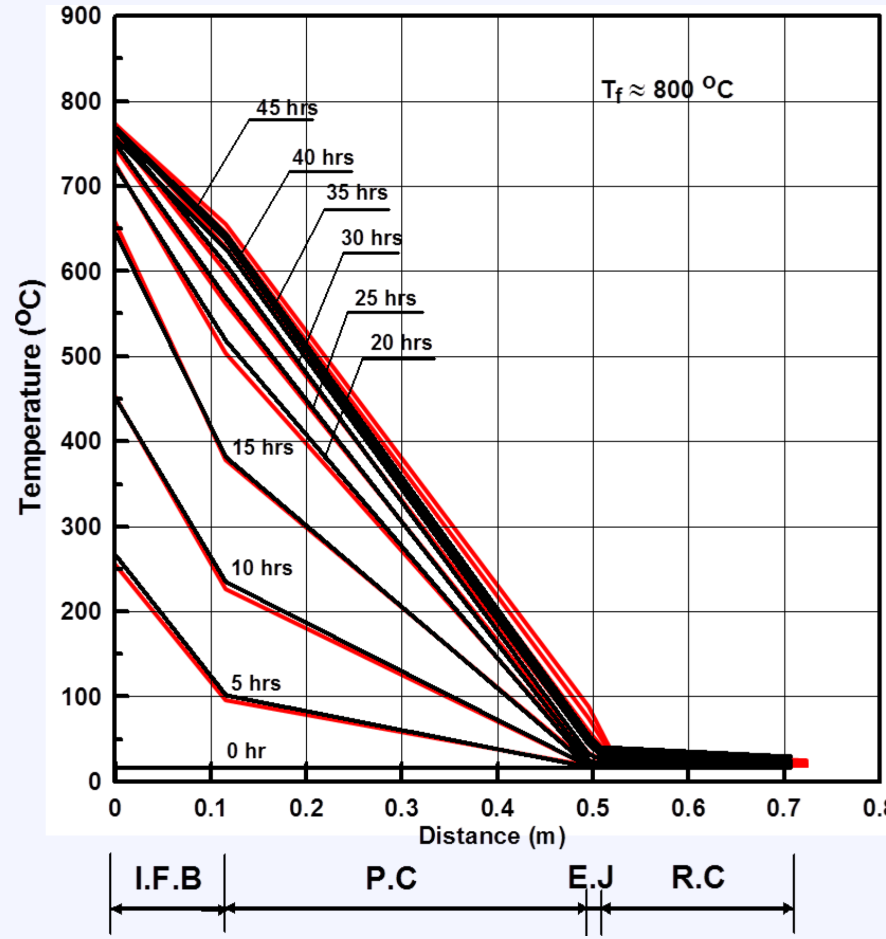
Balance of Plant



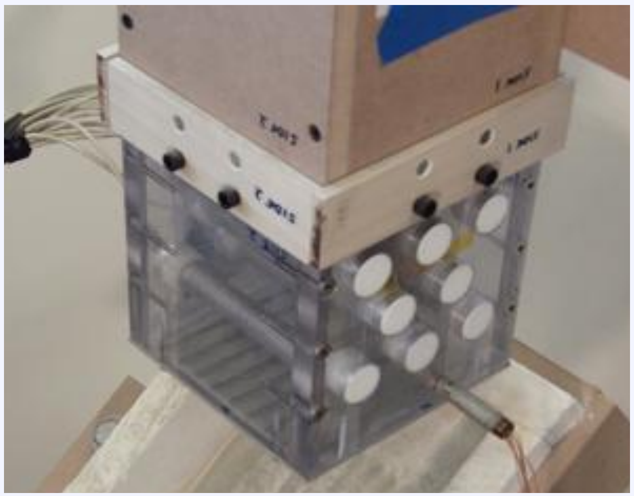
Task 3.1 Thermal Storage (KSU and Georgia Tech)

- Experimental evaluation and modeling of prototype thermal energy storage designs



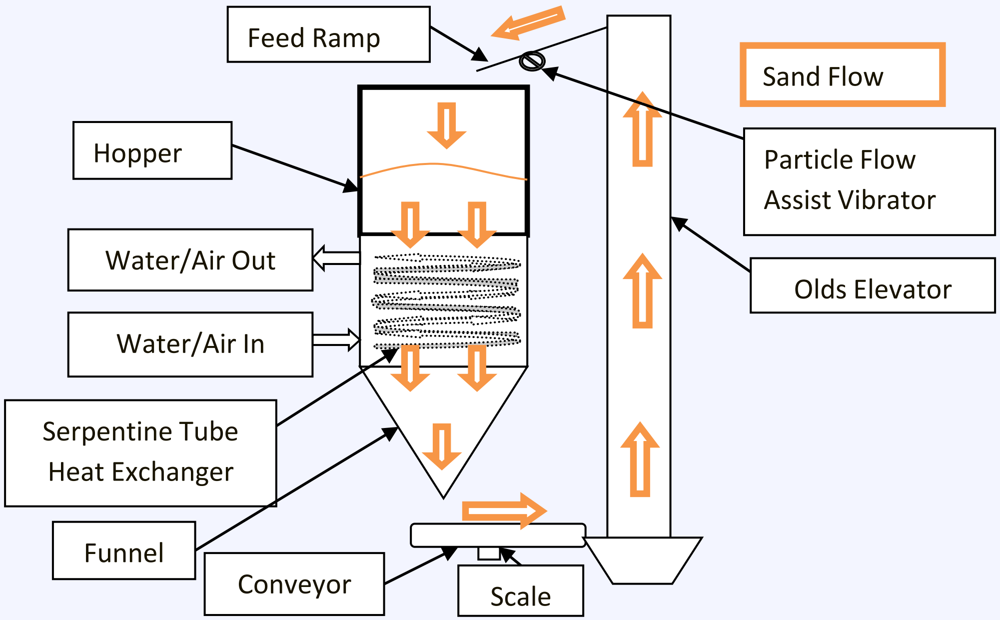


Task 3.2 Particle to Working Fluid Heat Exchanger (Georgia Tech)



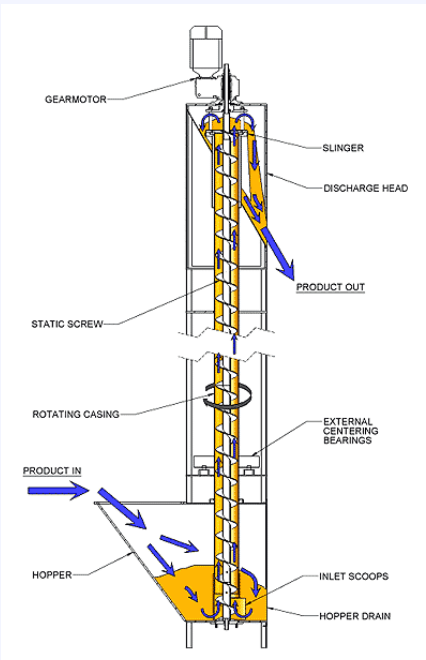
Bench-scale heat exchanger

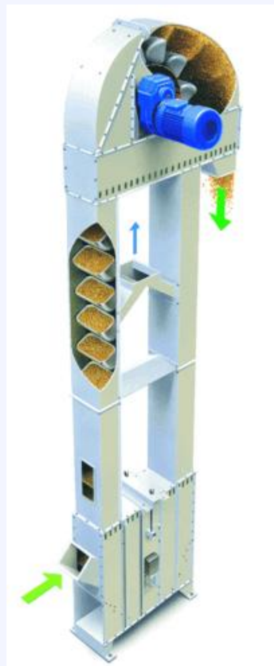
- Experimental evaluation of heat transfer coefficients & particle flow
  - Heat exchanger module designed and instrumented for continuous sand flow over heated tubes



Full-scale heat exchanger

Task 3.3 Particle Lifts (GT, SNL, DLR)





- Evaluate commercial particle lift designs
  - Requirements
    - 5 – 10 kg/s
    - 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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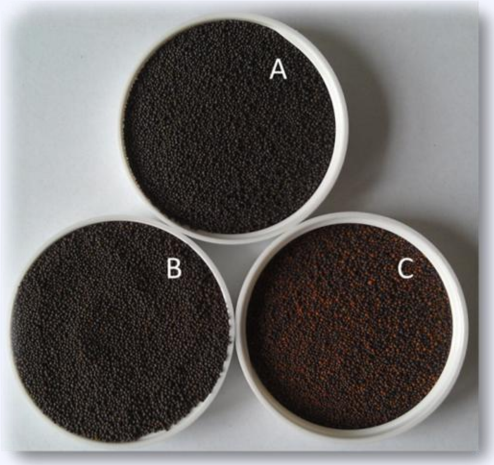
Future Work

- Receiver
  - Conduct optimization of receiver efficiency using CFD models
  - Perform tests with prototype receiver to investigate proposed enhancements
  - Continue evaluation of flow through porous media for increased residence time and particle heating

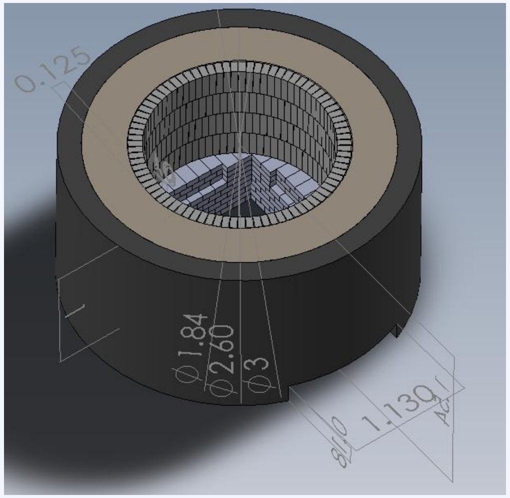
Future Work

- Particles
  - Complete optical characterization of particles
  - Initiate development of new formulation for increased solar absorptance
  - Identify methods to mitigate abrasion and attrition



Future Work

- Balance of plant
  - Continue testing of prototype thermal storage bins using new geometries
  - Perform particle-to-fluid heat exchanger tests to measure heat transfer coefficients over range of materials, configurations, and operating parameters
  - Continue investigation of particle elevators that satisfy requirements for flow rate, temperature, and particle retention



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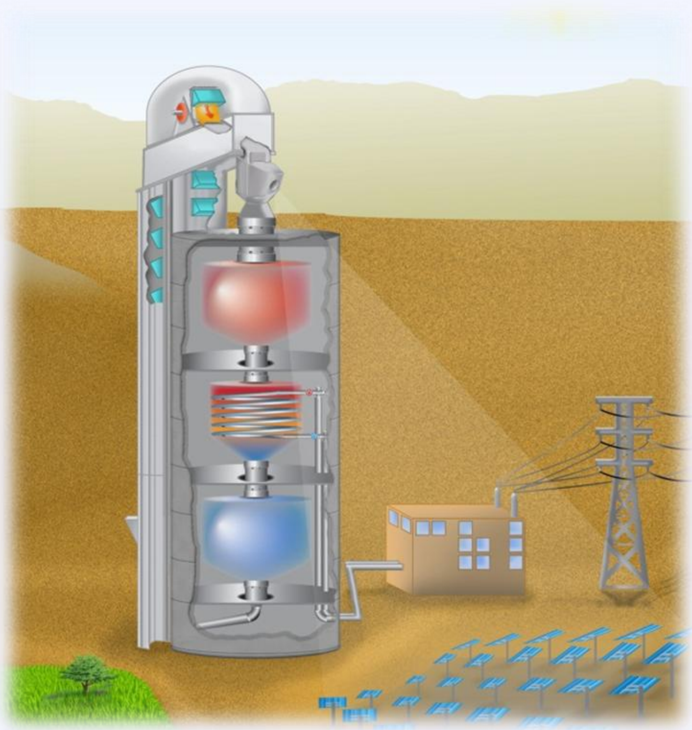
Questions?

Clifford K. Ho
ckho@sandia.gov
(505) 844-2384



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