Characterization of Convective and Particle Losses in High-Temperature Particle Receivers

Exceptional service in the national interest

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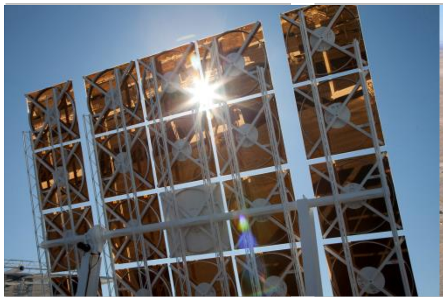

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SAND2019-XXXX

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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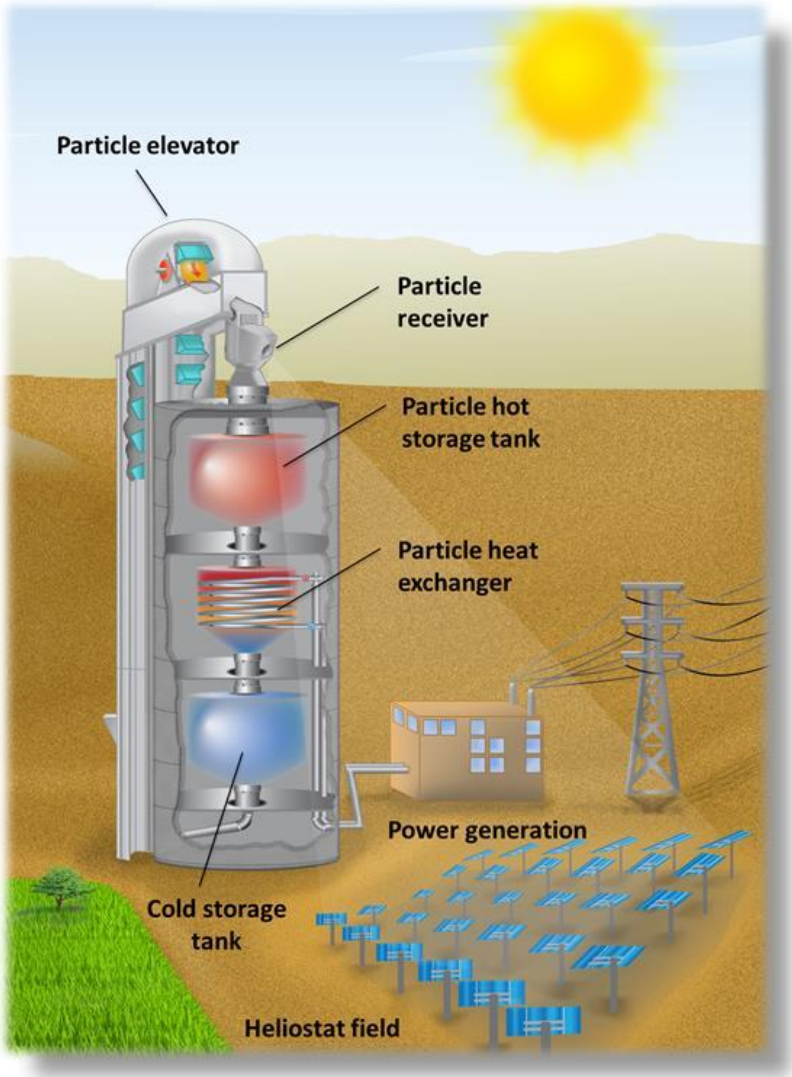
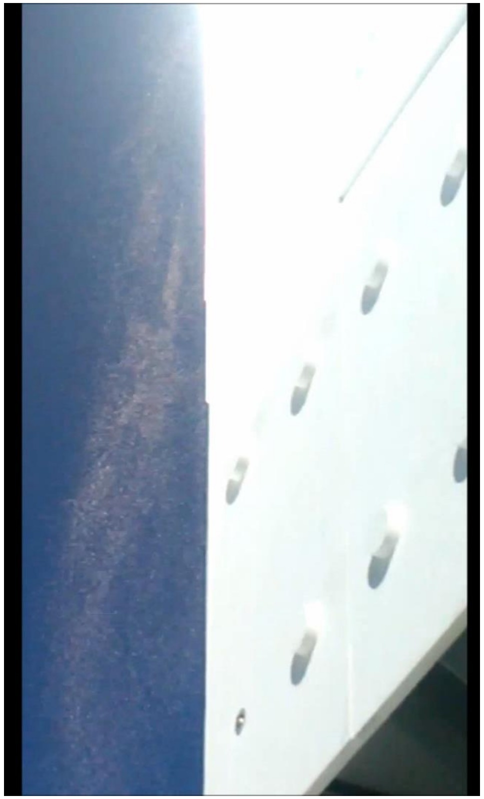
Introduction

- High-temperature particle receivers are being pursued to provide heat for sCO2 Brayton cycles



Problem Statement

- Particles can escape from the open aperture of a falling particle receiver
  - Inhalation/pollution hazard
  - Loss of particle inventory
- Need to minimize both particle *and* convective heat losses
  - Can imaging of particles be used to estimate convective heat losses?



Nov. 2, 2015
3/8” slot – free fall
280 micron ACCUCAST ID50
10-15 mph south wind
500 – 1000 suns

Project Objectives

- Task 1: Develop imaging methods to characterize particle and heat losses emitted from the aperture of a high-temperature particle receiver
  - Challenges
    - Small particle sizes (~100 microns) and long focal distances (5 – 10 m)
    - Fast frame rate required to capture particles
    - Discerning particle temperatures can be confounded by background and concentrated sunlight
- Task 2: Quantify particle emissions using standard air monitoring procedures and compare to OSHA and EPA standards
  - Challenges
    - Wind influences particle movement and collection locations
    - Testing is not continuous

Approach

- Imaging Methods
  - Work with UNM and AirPhoton to develop camera-based imaging methods and algorithms (Q1 – Q2)
  - Perform bench-scale tests at UNM and AirPhoton (Q2 – Q4)
  - Develop algorithms and models for particle and heat losses based on imaging data (Q2 – Q8)
- Air Monitoring
  - Identification of sampling methods using Sandia’s aerosol experts (Q1 – Q3)
  - Perform modeling, deployment, and testing (Q4 – Q8)

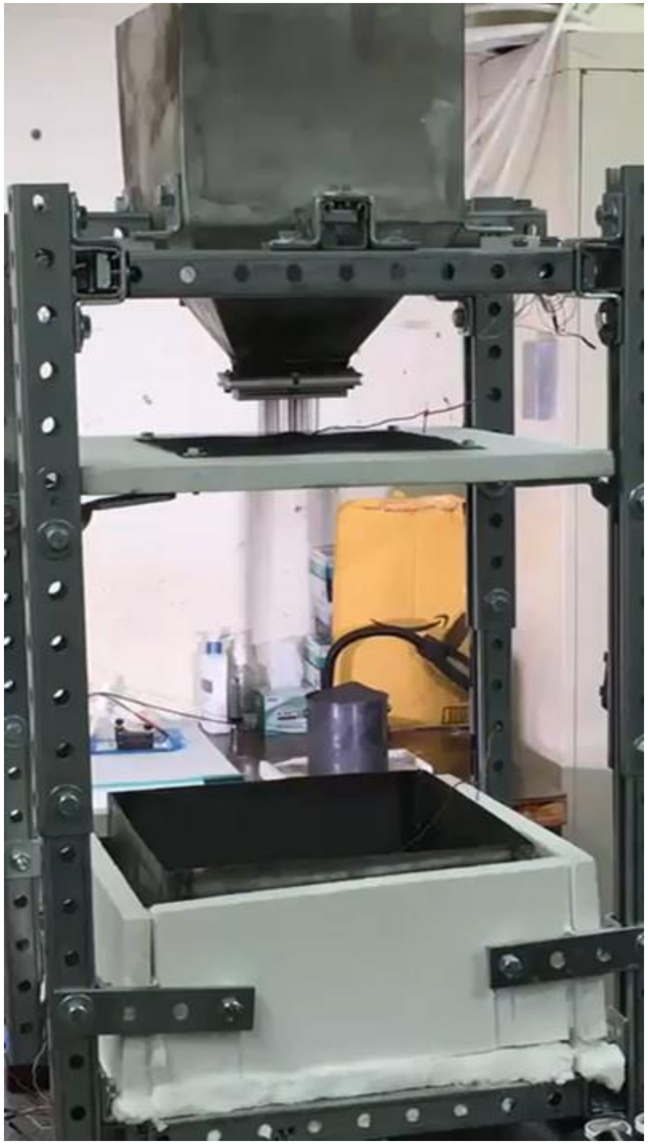
Key Outcomes

- Task 1: Imaging methods
  - Completed design requirements of imaging tools (Q1)
  - Lab testing and development (Q3 – Q4)
    - Demonstrated high-speed IR camera for capturing particle velocities and temperatures
    - Quantified particle attrition and mechanisms of fines generation
    - Documented testing results and algorithm development in ASME conference paper (July 15 – 18, 2019, Bellevue, WA)
- Task 2: Air monitoring
  - Completed 1st on-sun tests using air-sampling instruments to monitor small (<10 microns) and large (>10 microns) particle emissions
  - Documented results in ASME conference paper (July 15 – 18, 2019)
    - Particle exposure during on-sun testing << 15 mg/m^3 (per NIOSH)

Particle Imaging (UNM)

- Preliminary Testing

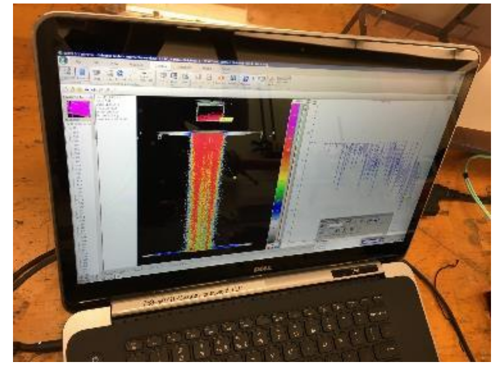
Infratec High-Speed IR Camera

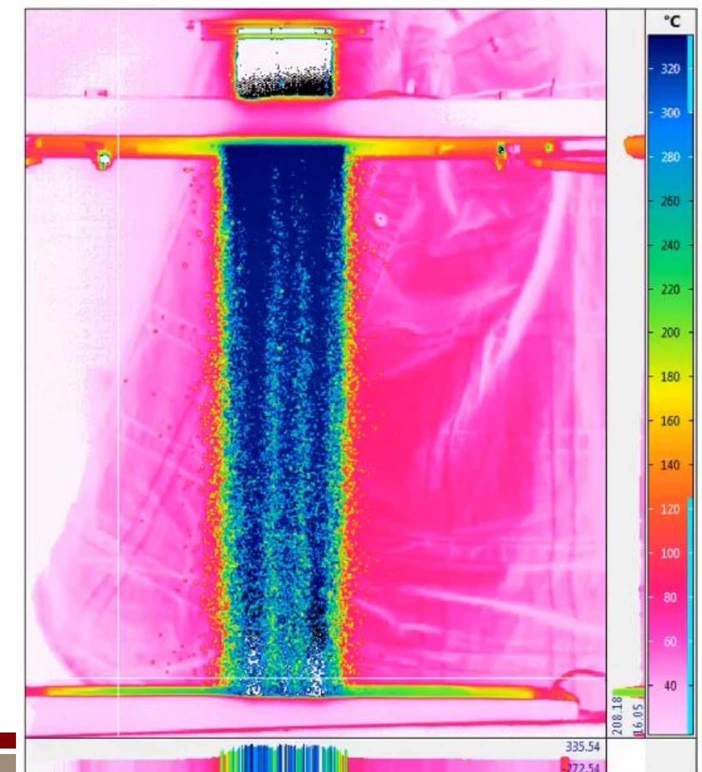


Hot particles falling through system

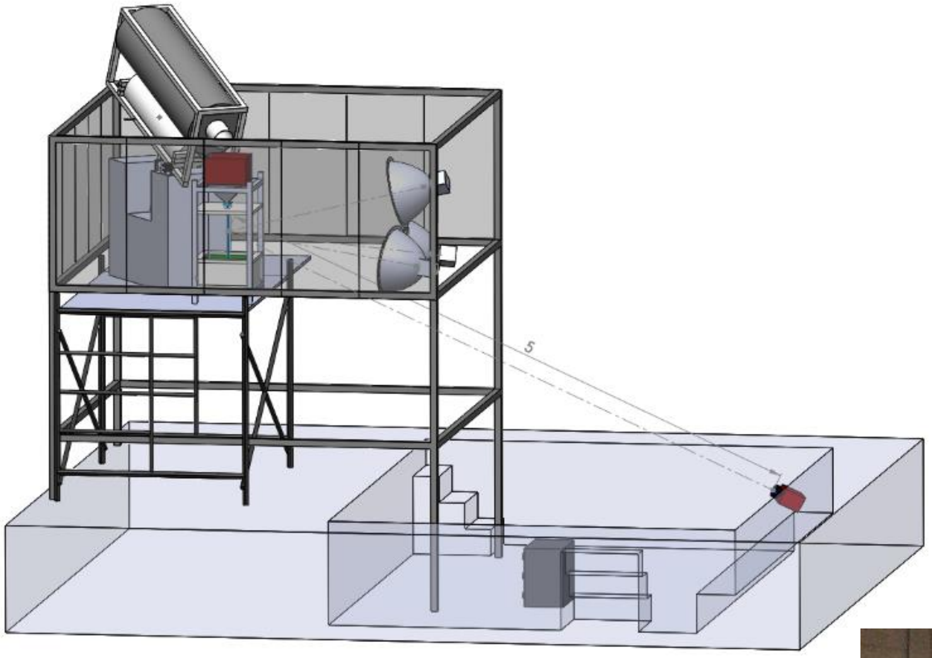
Particle Imaging (UNM)

- Preliminary Testing
  - Videos: High-speed image from visible camera (left) and false-color temperature profile from IR camera (right)





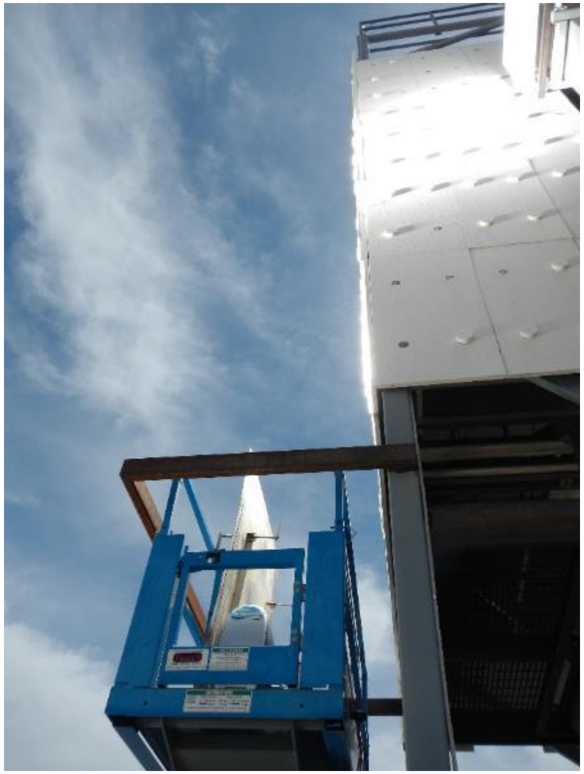
Particle Imaging (UNM)



Air Monitoring

Performed on-sun tests with the Malvern Spraytec particle analyzer to evaluate large particle emissions and size distributions (tens to hundreds of microns)
April 5, 2018, Sandia National Laboratories

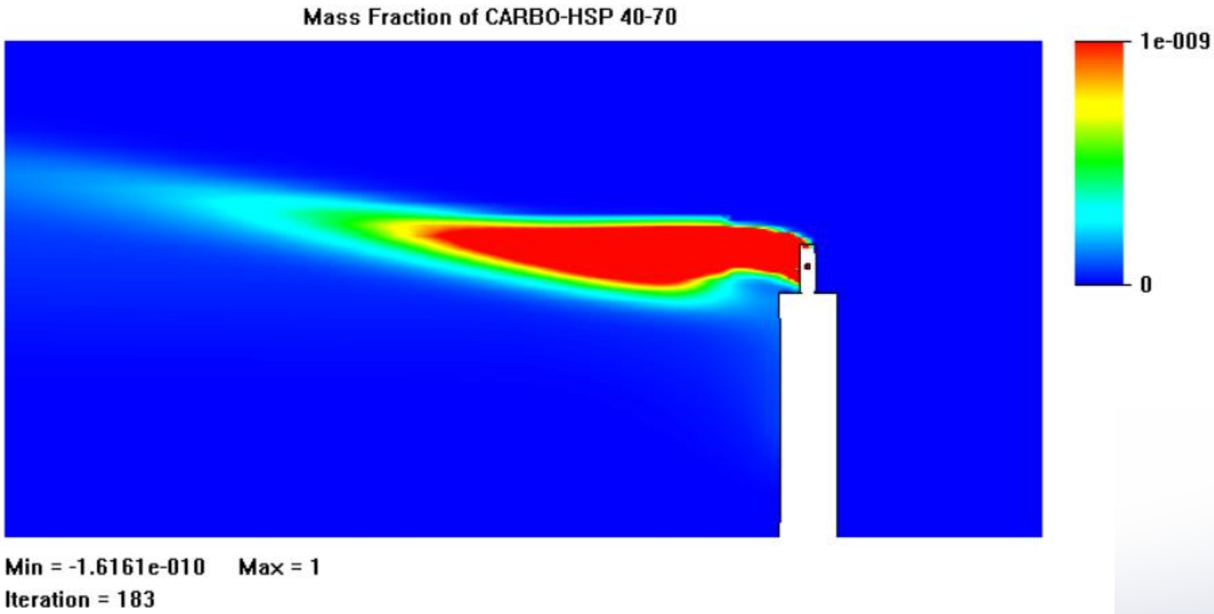




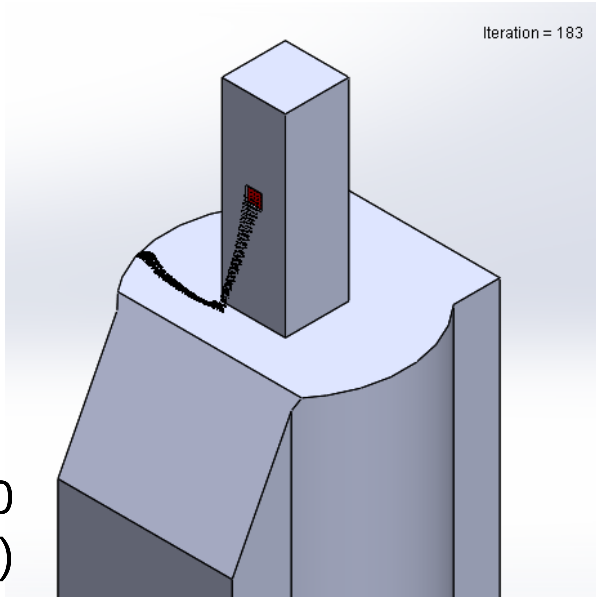
Air Monitoring

Used traditional air samplers to evaluate small particle emissions (submicron to micron) at the base and top of the tower

Particle Emission & Dispersion Modeling



Simulation of small particle (~1-10 micron) concentrations



Simulation of large particle (~350 microns)

Impact

- Imaging methods and results of this work will improve and enable safe operation of advanced particle receiver designs to meet DOE goals

Questions?

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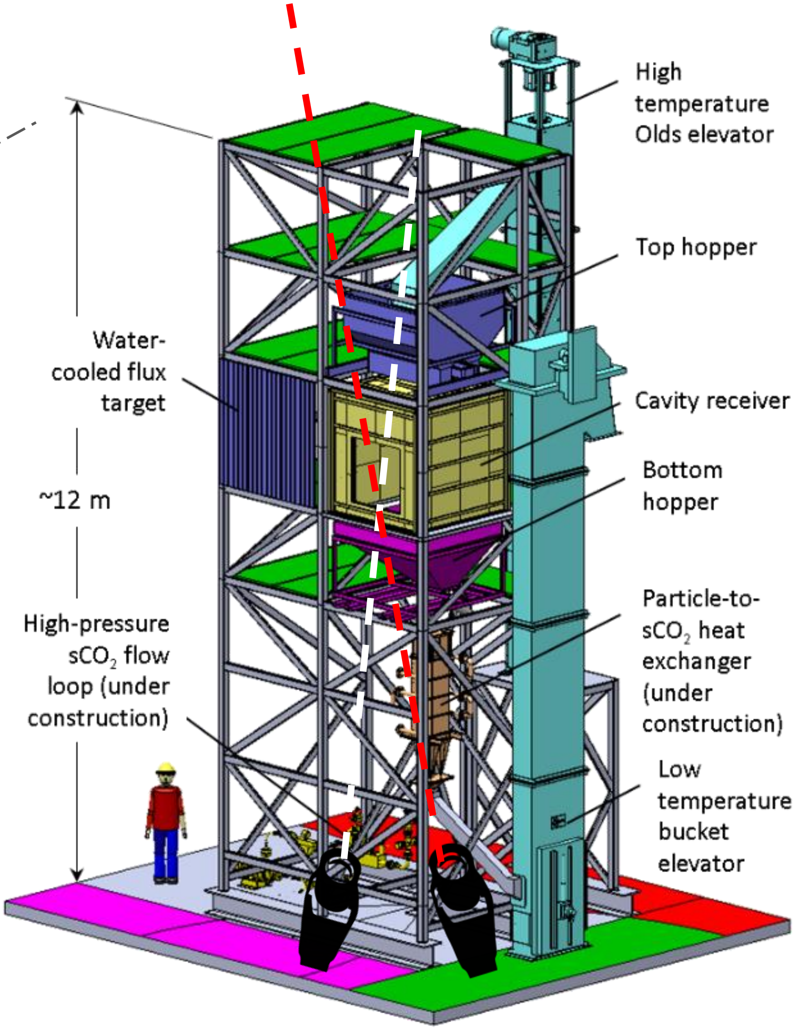
Particle Imaging

On-sun particle receiver testing at the National Solar Thermal Test Facility at Sandia National Laboratories, Albuquerque, NM



High-Temperature Particle Receiver