High-Temperature Particle-to-sCO2 Heat Exchanger

SuNLaMP 1507

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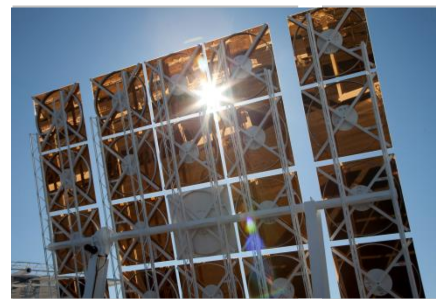

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NNSA National Nuclear Security Administration

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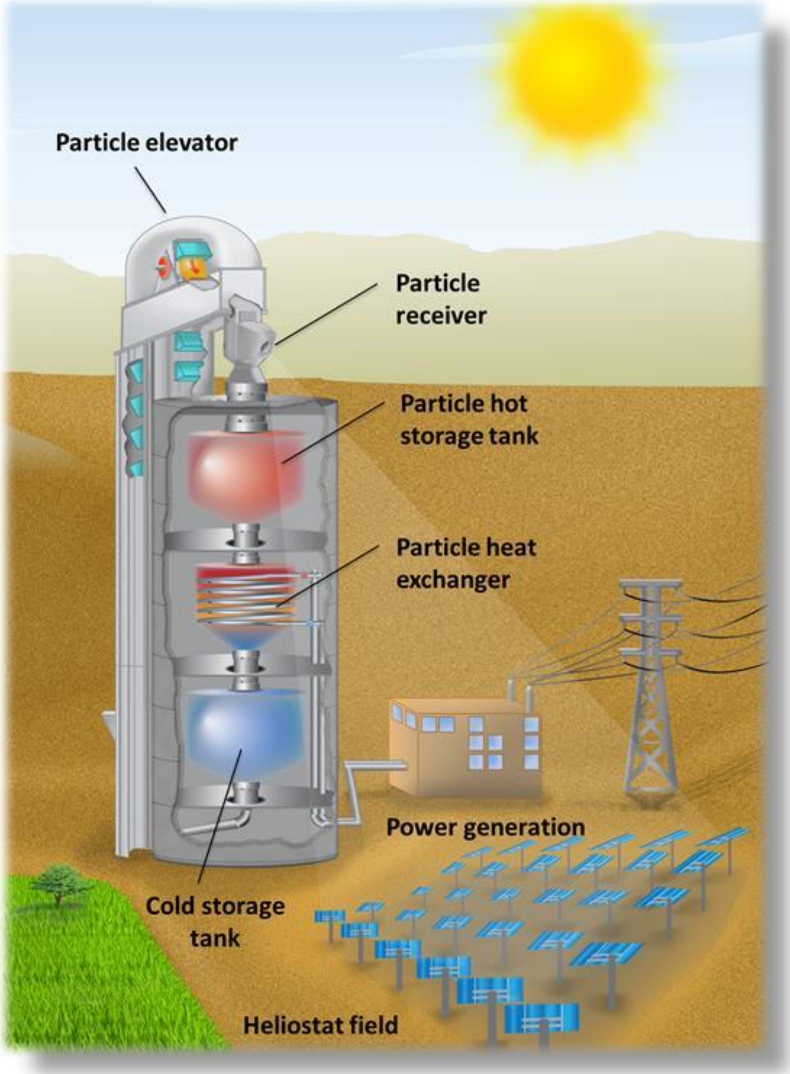
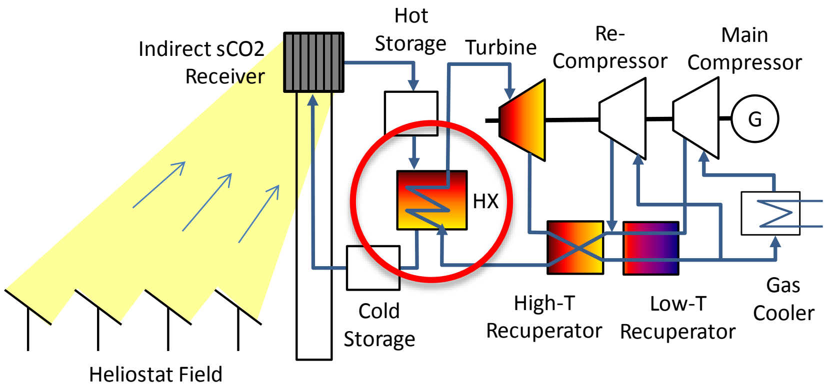
Introduction

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

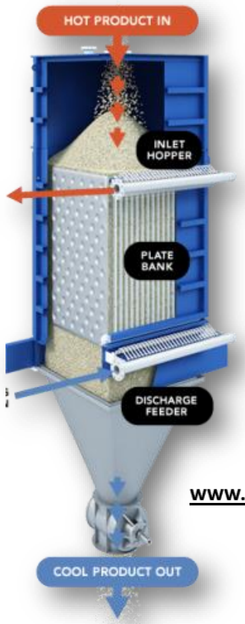


Problem Statement

- Particle-to-sCO2 heat exchangers do not exist
  - sCO2 ≥ 700 °C at ≥ 20 MPa
- Challenges
  - Particle-side heat transfer
  - Thermomechanical stresses
  - Materials
    - High operating temperatures and pressures
    - Erosion
  - Costs



Solarized sCO2 recompression Brayton cycle



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Objectives and Approach

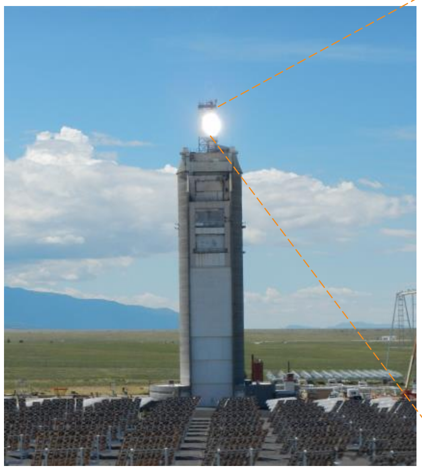
- Evaluate and downselect among alternative designs using Analytic Hierarchy Process (Ho et al., 2018)
- Construct, and test prototype particle heat exchanger that can heat sCO2 to 700 °C at 20 MPa for 100 kW prototype
- Integrate final design with Sandia's falling particle system

Heat Exchanger	Advantages	Disadvantages
Fluidized Bed (Babcock & Wilcox)	High heat-transfer coefficients	Energy and mass loss from fluidization
Moving packed bed - shell/tube (Solex Thermal Science)	Gravity-fed particle flow; low erosion	Low particle-side heat transfer
Moving packed bed - (shell/plate (Vacuum Process Engr)	High potential surface area for particle contact; low erosion	Requires diffusion-bonding of plates

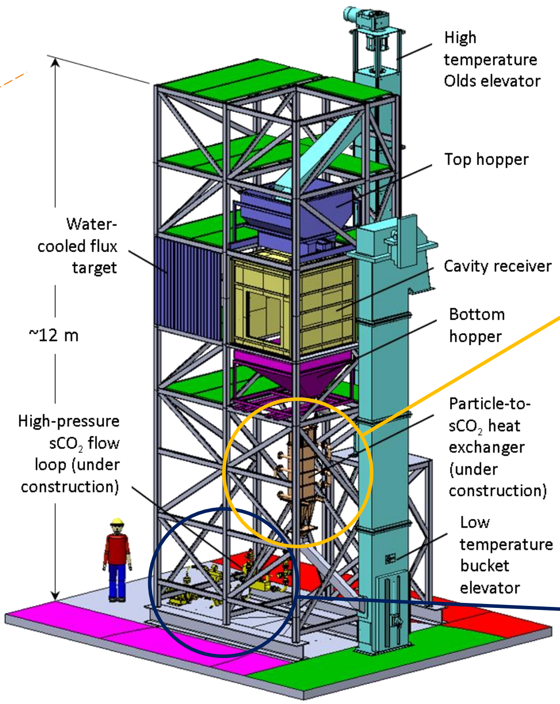
Key Outcomes and Impact

- Teamed with industry to design fluidized and moving-packed-bed particle/sCO2 heat exchangers
- Measured particle/wall heat transfer coefficient at ~200 W/m^2-K for shell-and-plate design
- Performed particle flowability tests at 600 °C
- Designed 100 kW_t sCO2 flow system for integration with heat exchanger
- **Impact**: Demonstration of first solarized heating of sCO_2 using particles (summer 2019)

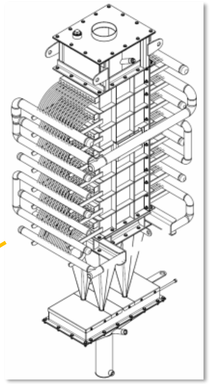
Integrated System



Particle receiver testing at the National Solar Thermal Test Facility at Sandia National Laboratories, Albuquerque, NM

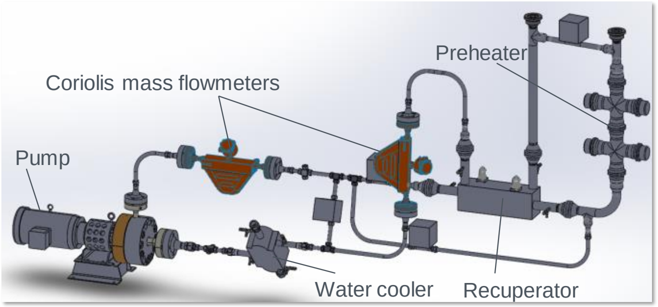


High-Temperature Particle Receiver



Solex/VPE/Sandia particle/sCO2 shell-and-plate heat exchanger

- Heat duty = 100 kW
- $T_{particle,in}$ = 775 °C
- $T_{particle,out}$ = 570 °C
- $T_{sCO2,in}$ = 550 °C
- $T_{sCO2,out}$ = 700 °C
- $\dot{m}$ = 0.5 kg/s



sCO_2 flow system provides pressurized sCO_2 at 550 °C to heat exchanger for test and evaluation

Questions?

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Technical Challegnes

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Design Criteria	Notes
Cost	Want low cost of prototype and larger scale systems (< $150/kW$_t$)
Heat Transfer Coefficient	Want large overall heat transfer coefficient (>100 W/m^2-K)
Structural Reliability	Want maximum allowable working pressure > 20 MPa at minimum design metal temperature of 750 C; long-term reliability
Manufacturability	Want ease of manufacturing and demonstrated ability to build
Parasitics & Heat Losses	Want low power requirements, pressure drop, and heat losses
Scalability	Need to be able to scale up to ~20 MW$_t$ thermal duty
Compatibility	Can be readily integrated with particle receiver and sCO2 flow loop
Erosion & Corrosion	Want to minimize thinning of walls and tubes from particle and sCO2 flow; need to ensure 30 year lifetime
Transient Operation	Want to minimize transient start-up and impact of thermal stresses
Inspection Ease	Want ability to inspect internals of the heat exchanger to evaluate corrosion, erosion, fatigue, etc.