Particle-to-sCO2 Heat Exchanger Designs for Concentrating Solar Power

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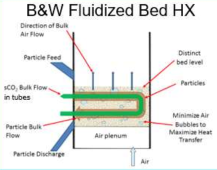
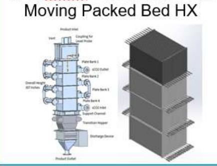
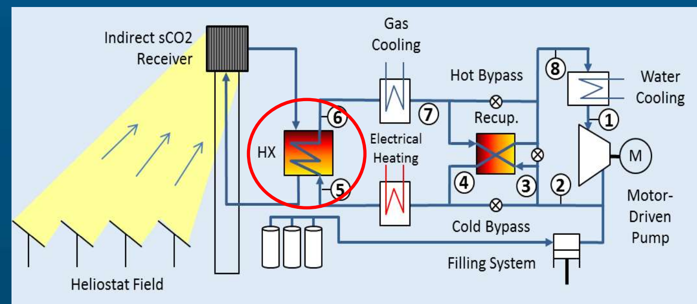
Problem Statement

- Conventional molten-salt central receiver systems are limited to temperatures <600 °C
- Advanced power cycles (combined air Brayton, supercritical CO_2 Brayton) require higher temperatures (>700 °C)
- Particle receivers are being investigated to achieve these higher temperatures, but particle heat exchangers operating at necessary temperatures and pressures (>20 MPa) do not exist

Particle/sCO_2 Heat Exchanger Design Options

Design Options	Pros	Cons	Risk Mitigation
B&W Fluidized Bed HX 	• High heat transfer coefficient, low heat transfer area • Vast industry experience	Parasitic power requirements and heat loss from fluidizing gas	Minimization of fluidization velocity to reduce power requirements and heat loss through CFD modeling
Solex – Shell-and-Tube Moving Packed Bed HX 	• Gravity-driven flow • Tubes can handle high-pressure sCO_2 • Lower pressure drop of sCO2 in tubes relative to plates	Particle flow stagnation area on top of tube and shadow area beneath tube may impede heat transfer	Improve particle/tube heat transfer via staggered tube arrangement with optimized spacing and/or extended surfaces
VPE/Solex – Shell-and-Plate Moving Packed Bed HX 	• Gravity-driven flow • High potential surface area for particle contact • Higher heat transfer coefficient than shell-and-tube due to narrow channels and large surface area	Thermal gradients and warping of plates, numerous nozzles, potential for non-uniform particle flow	Use of multiple plate banks to minimize thermal gradient, proper spacing of plates, and adequate thermal insulation around nozzles

Solarized Supercritical CO_2 (sCO2) Flow System



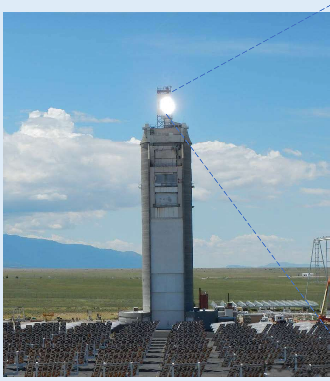
Objectives

- Design, develop, and test the world's first particle/sCO_2 heat exchanger to enable solarized sCO2 Brayton cycles operating at >50% efficiency
  - Particle temperature ≥ 720 °C
  - sCO_2 temperature ≥ 700 °C
  - sCO_2 pressure up to 20 MPa
  - Overall heat transfer coefficient ≥ 100 W/m^2-K
  - Total cost of power-block components ≤ \$900/kW$_e$

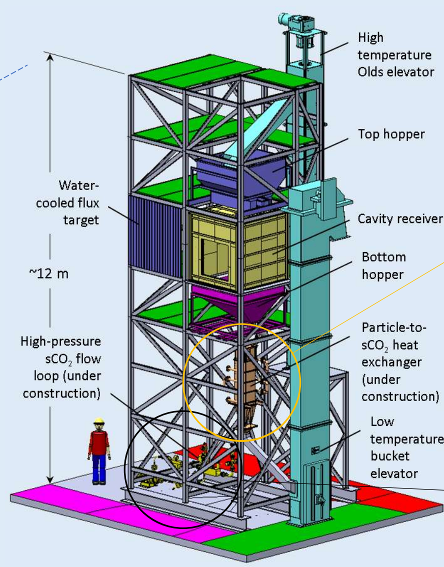
Approach

- Work with industry to design and develop particle-sCO_2 heat exchanger that meets cost/performance requirements
- Evaluate alternative designs including fluidized-bed and moving packed-bed (shell-and-tube, shell-and-plate) heat exchangers
- Integrate heat exchanger with high-temperature falling particle receiver and modular sCO_2 flow loop

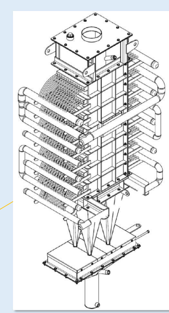
Integrated System



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

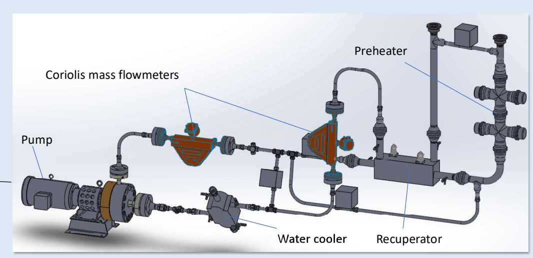


High-Temperature Particle Receiver



Solex/VPE 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

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