Particle Heat Exchangers:

Development and Testing of a 20 kW_t Moving Packed-Bed Particle-to-sCO_2 Heat Exchanger

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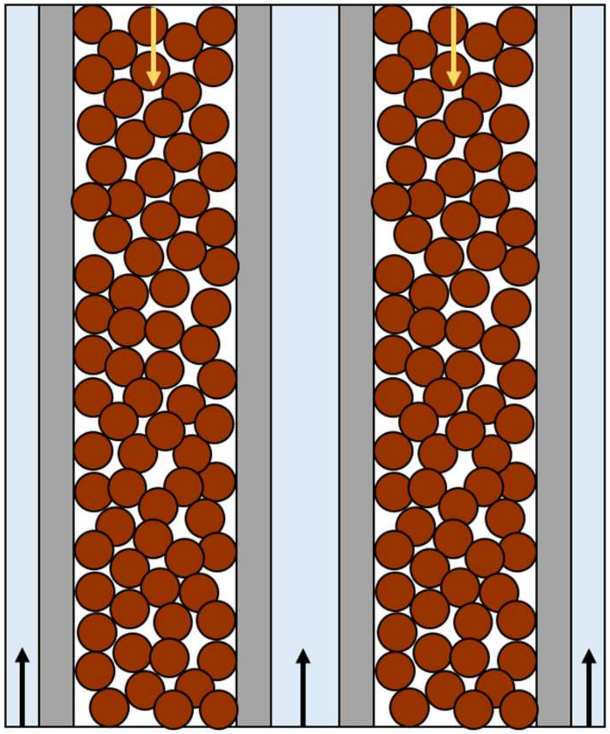
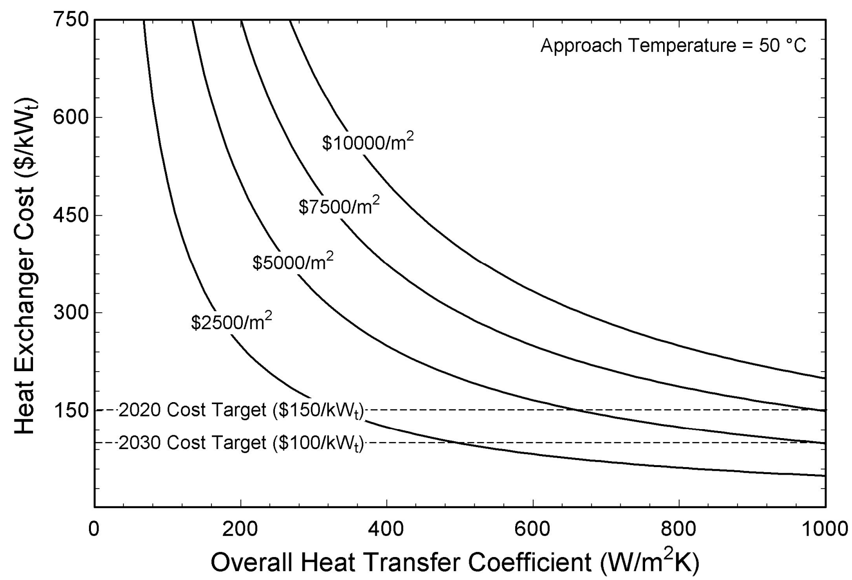
Moving Packed-Bed Heat Exchanger Introduction



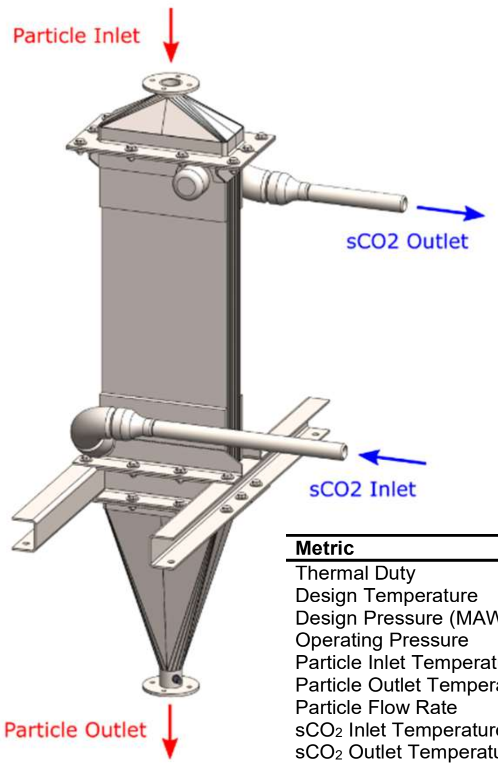
- Particle CSP is being developed to enable high efficiency sCO_2 power cycles
- The particle/sCO_2 heat exchanger is a critical enabling technology for these systems

Moving Packed-Bed Heat Exchanger for Particle CSP



- Overall heat transfer coefficient needs to approach 600 W/m^2-K for particle heat exchangers to meet 2020 cost targets with current manufacturing (>$5000/m^2)
- With reduction in manufacturing cost, overall heat transfer coefficients between 400-500 W/m^2-K could be acceptable

20 kW_t Stainless Steel Heat Exchanger Design



Metric	Value	Units
Thermal Duty	20	kW
Design Temperature	550	°C
Design Pressure (MAWP)	20.0	MPa
Operating Pressure	17.0	MPa
Particle Inlet Temperature	500	°C
Particle Outlet Temperature	340	°C
Particle Flow Rate	0.112	kg/s
sCO_2 Inlet Temperature	290	°C
sCO_2 Outlet Temperature	450	°C
sCO_2 Flow Rate	0.103	kg/s
sCO_2 Pressure Drop	<40	kPa

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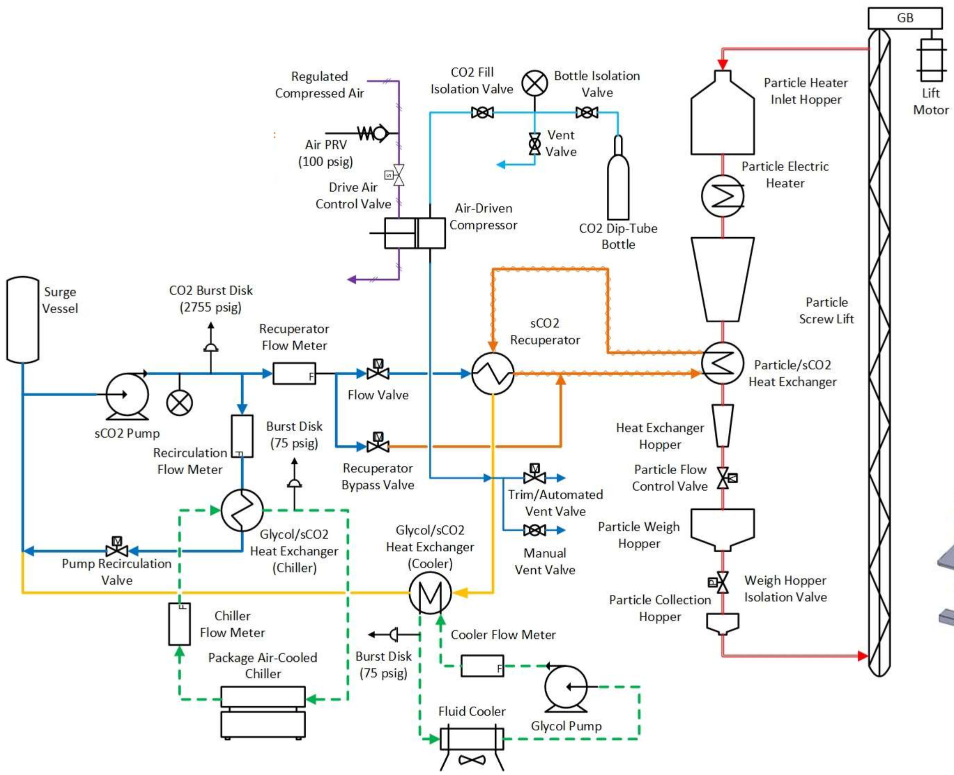
Prototype heat exchanger was developed to evaluate novel design features in G3P3:

- Narrow plate spacing (~3 mm)
- Increase approach temperature
- Bonded/brazed construction
- Integral porting
- Flow distribution inside of plate
- Welding headers across bond lines

Difference in G3P3 heat exchanger:

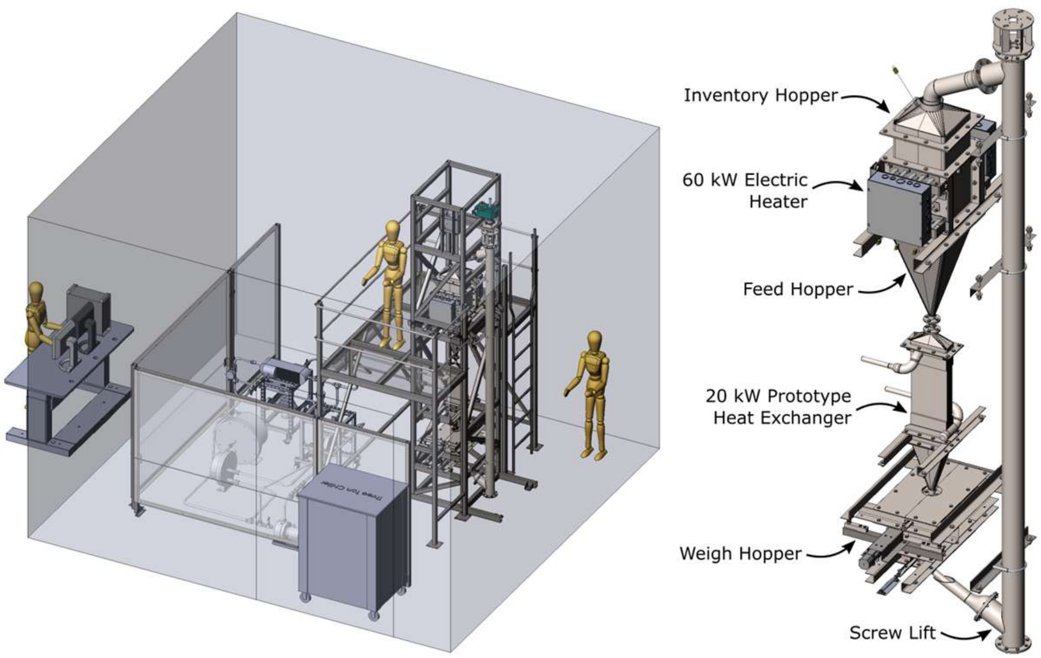
- Nickel alloy construction
- Multiple inlets/outlets
- Higher temperature/pressure operation

Heat Exchanger Test Facility



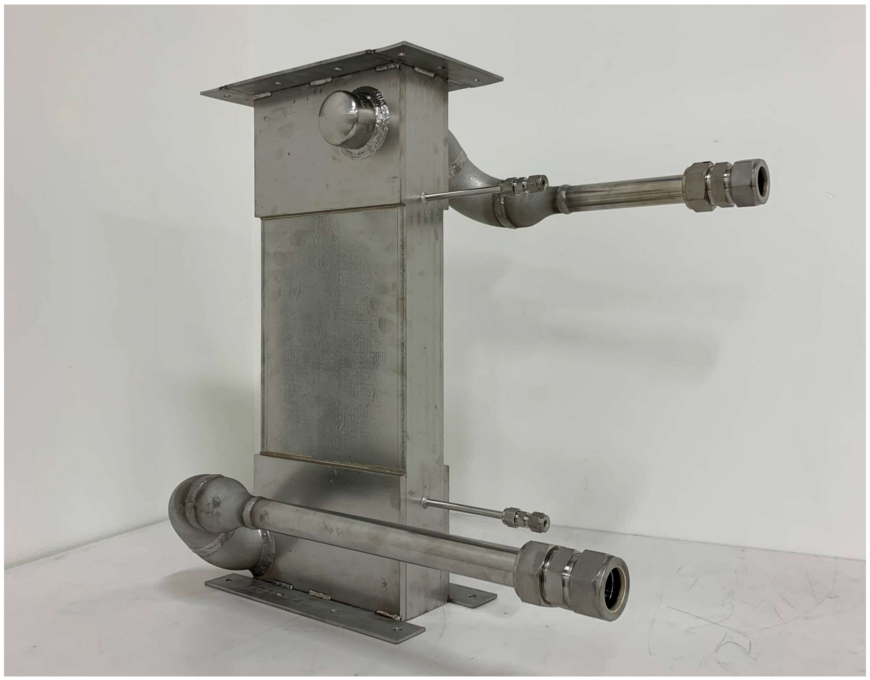
Process Flow Diagram

Physical System Layout



- Integrated particle/sCO_2 flow loop design was developed to locate entire system in a dedicated indoor test cell at NSTTF

Heat Exchanger Manufacturing and Installation



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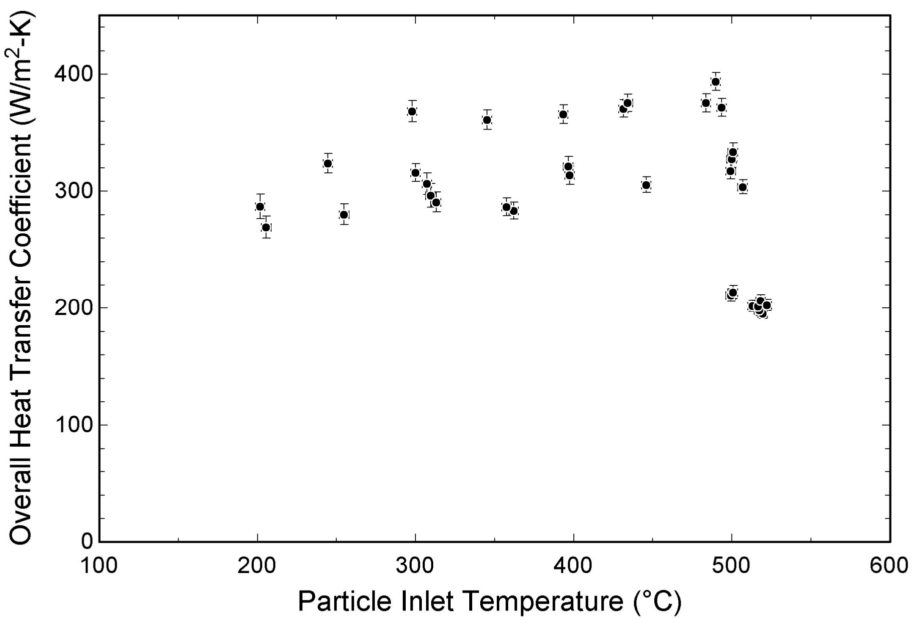
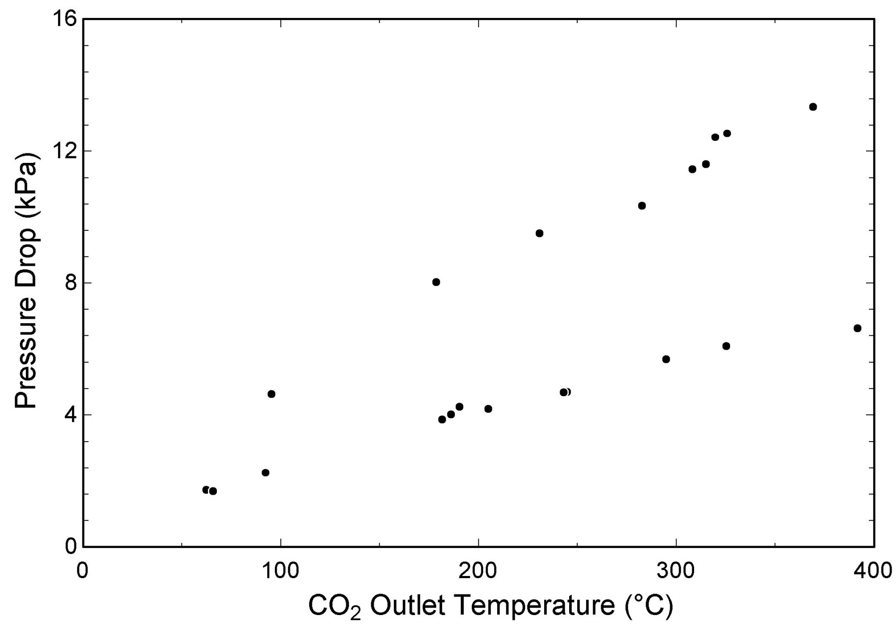
- Heat exchanger core was manufactured at VPE and shipped to Sandia for installation in the system and testing

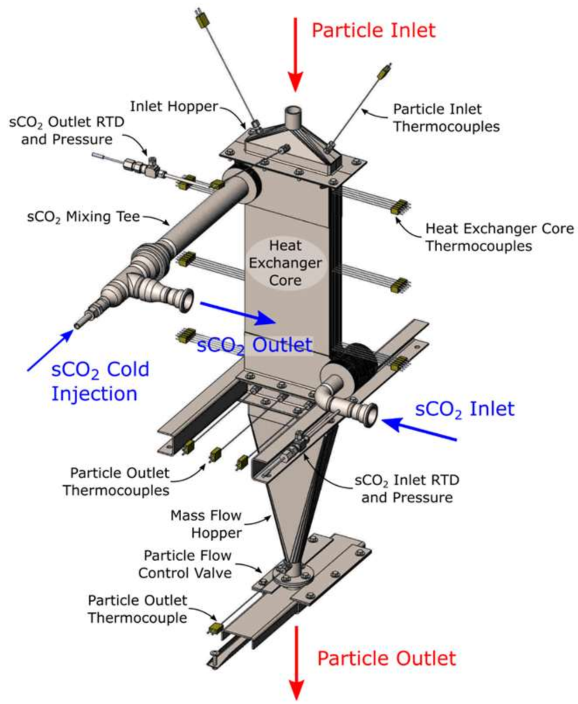
Postprocessed Overall Heat Transfer Coefficient





- Heat exchanger performance measured over a wide range of operating conditions
- Overall heat transfer coefficients up to 400 W/m^2-K were measured at high flow rate

20 kW_t Nickel Heat Exchanger Project



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VPE VACUUM PROCESS ENGINEERING

Design revisions:

- Design temperature: 800 ^oC
- Design pressure: 25 MPa
- Nickel alloy construction (IN617)
- Overall HTC: >450 W/m^2-K
  - <3 mm particle channel width
  - sCO_2 microchannel enhancement
- Pressure Drop: <30 kPa
- Reduction in material per surface area

Conclusions

- Integrated particle/sCO_2 heat exchanger test facility was developed targeting short lead time and low cost
- Novel design features for a moving packed-bed particle/sCO_2 heat exchanger were evaluated in a small-scale heat exchanger prototype
- Performance has demonstrated design point heat transfer coefficients above 300 W/m^2-K and off design conditions approaching 400 W/m^2-K
- System is currently being upgraded for Gen3 conditions and manufacturing a prototype high nickel alloy design targeting 500 W/m^2-K

Sandia can provide testing services for industry and university led research projects on particle/sCO_2 heat exchangers up to 40 kW_t

Acknowledgements

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