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Sandia National Laboratories

Design and Testing of a Prototype Particle/sCO_2 Heat Exchanger at Gen3 Operating Conditions

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SolarPACES 2022

Power Cycles

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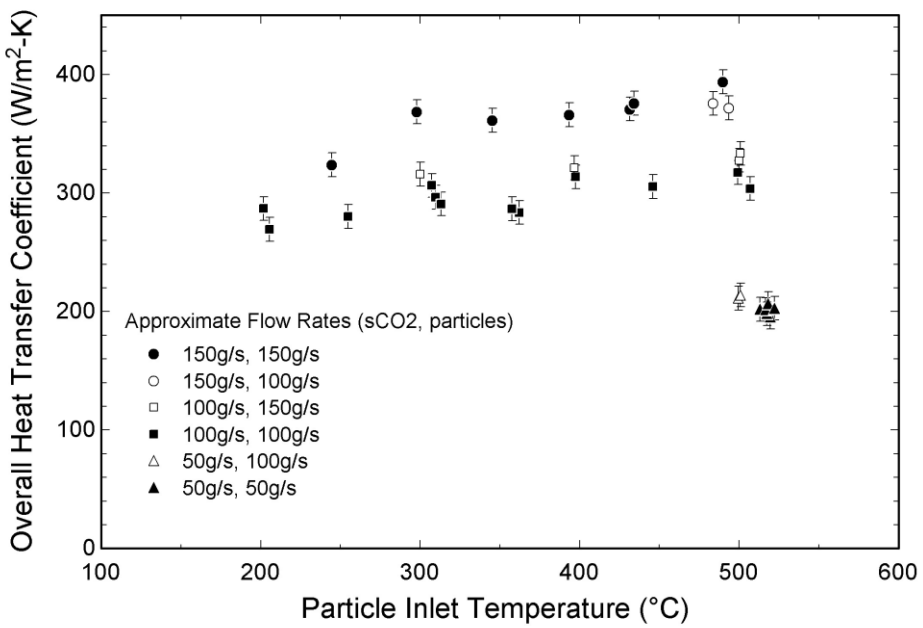
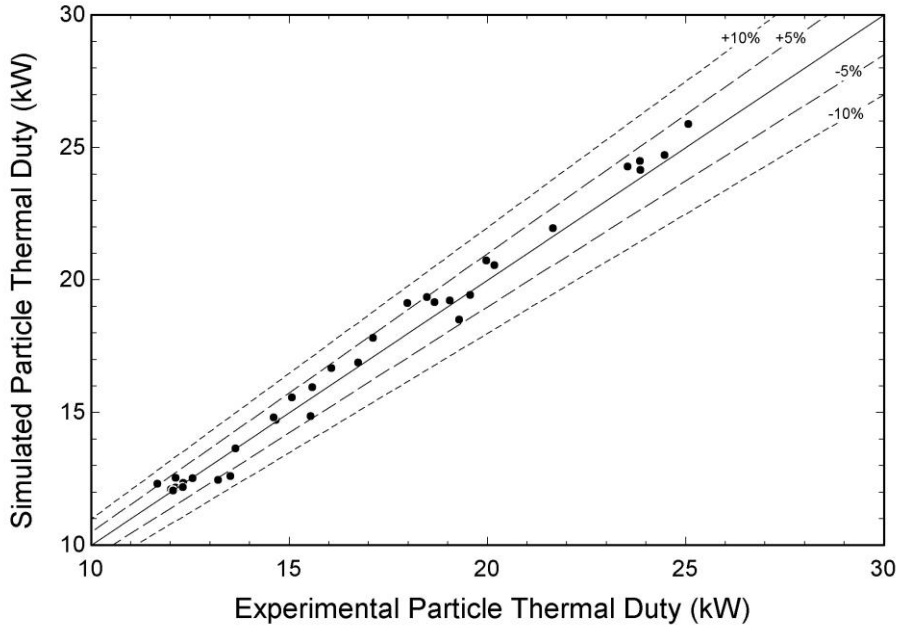
Introduction

- 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 exchangers are a promising option
- Solex, VPE, and Sandia have been collaboratively developing advanced moving packed-bed heat exchangers

Prior 20 kW_t Stainless Steel Prototype Testing



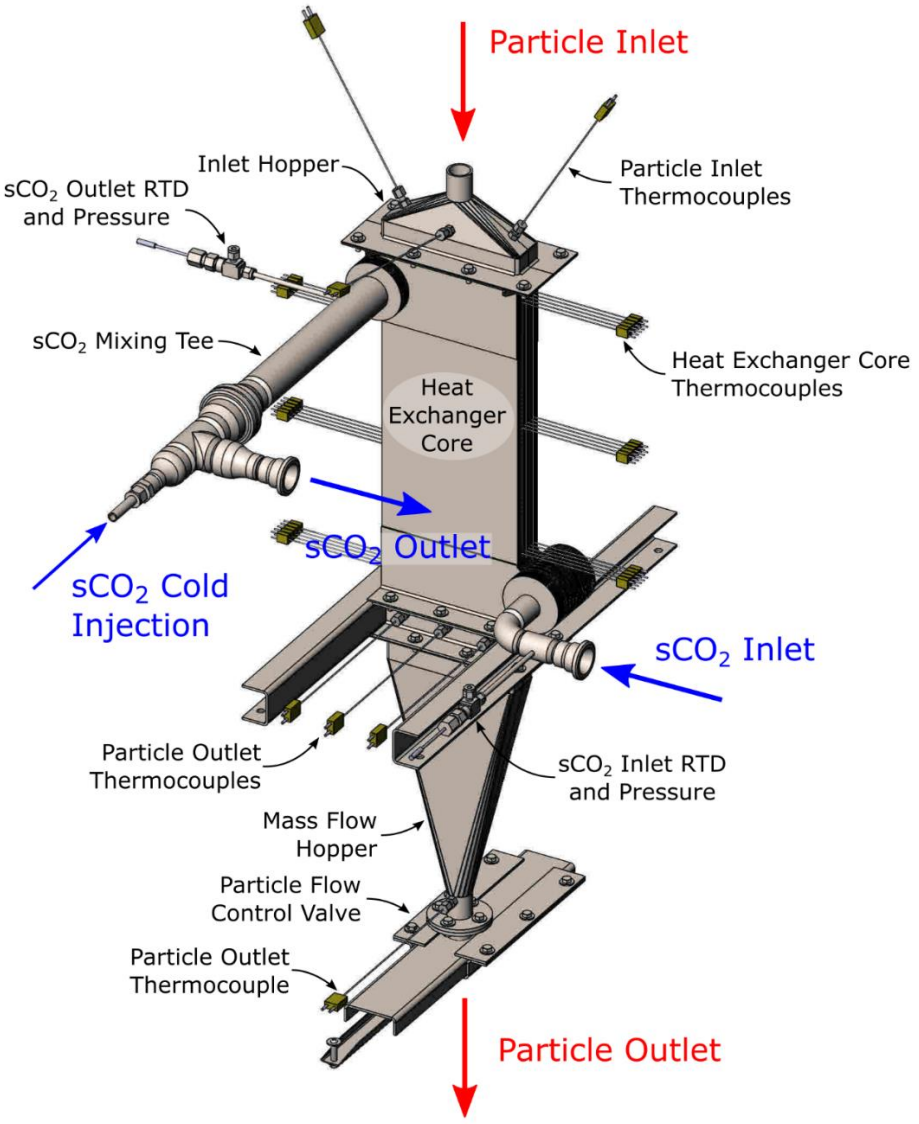


Prototype heat exchanger designed and built as part of G3P3 program

Prototype performance measured using integrated particle and sCO_2 flow loops

Data was used to verify heat exchanger thermal model in Sierra/Aria

20 kW_t Nickel Heat Exchanger Design Requirements



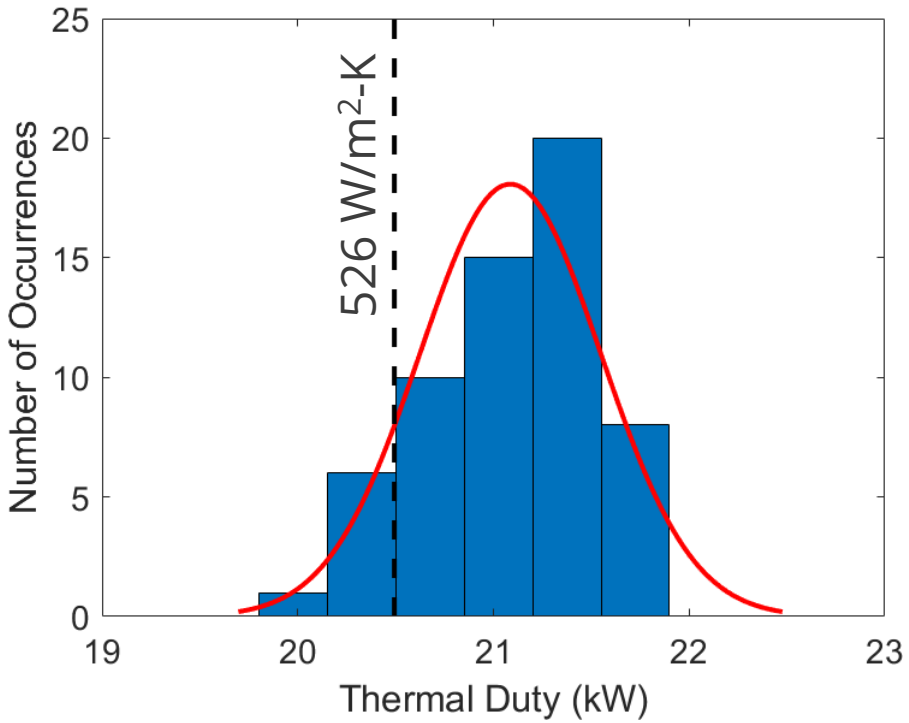
Design Requirements:

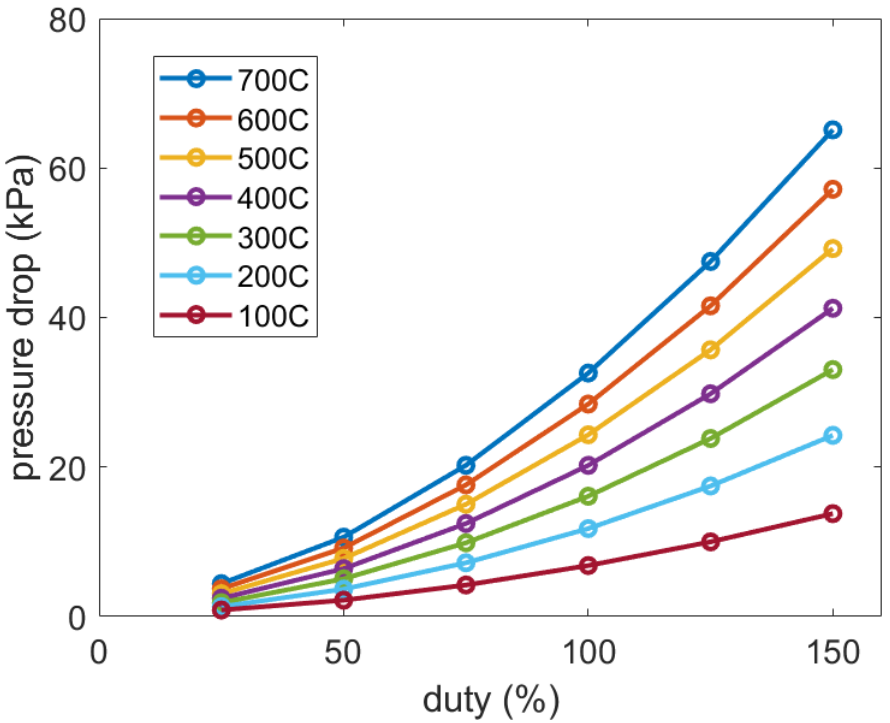
- Design temperature: 800 ^oC
- Design pressure: 25 MPa
- Nickel alloy construction (IN617)
- Overall HTC: >450 W/m^2-K
  - <3 mm particle channel width
  - sCO_2 microchannel enhancement
- Pressure Drop: <30 kPa
- Reduction in material per surface area

SOLEX THERMAL SCIENCE

VPE VACUUM PROCESS ENGINEERING

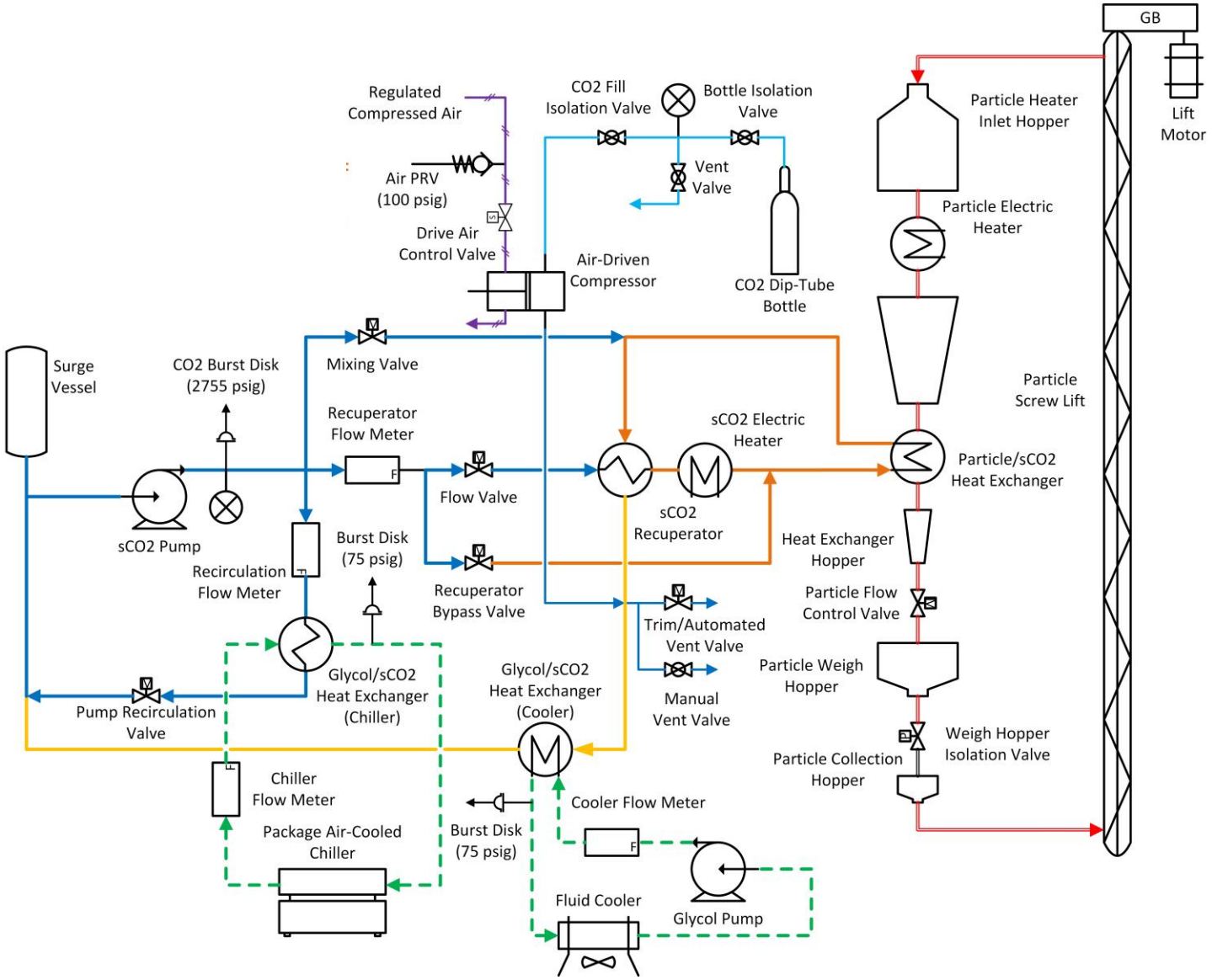
20 kW_t Nickel Heat Exchanger Modeled Performance



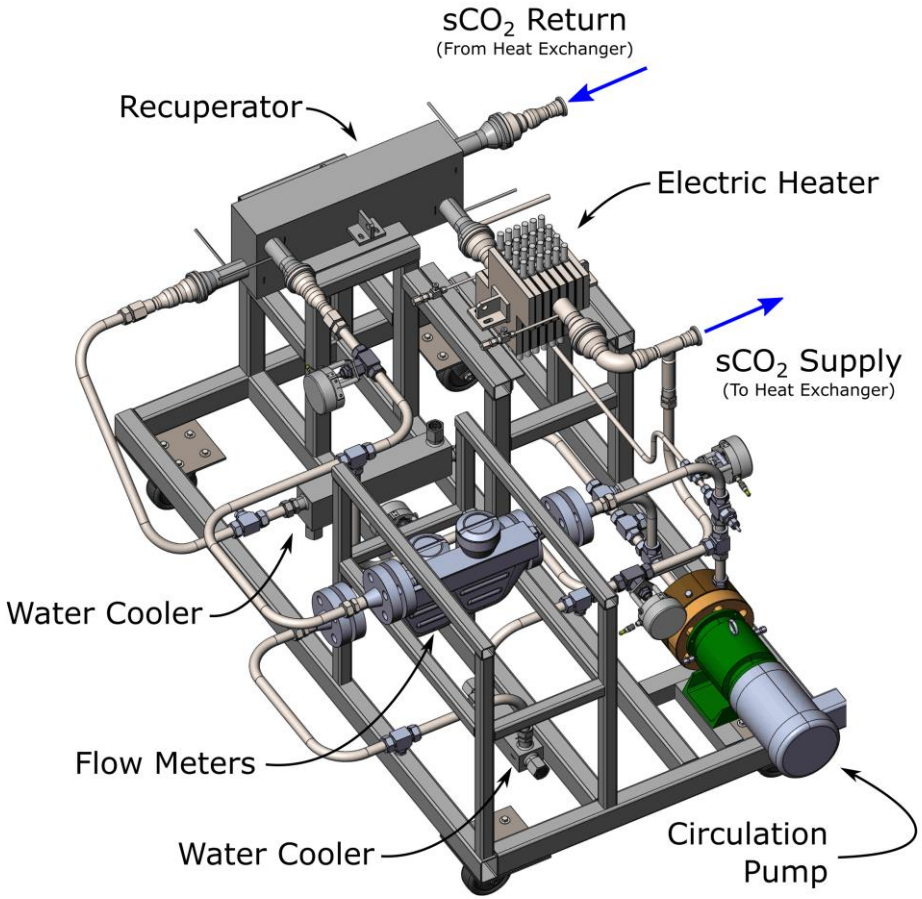


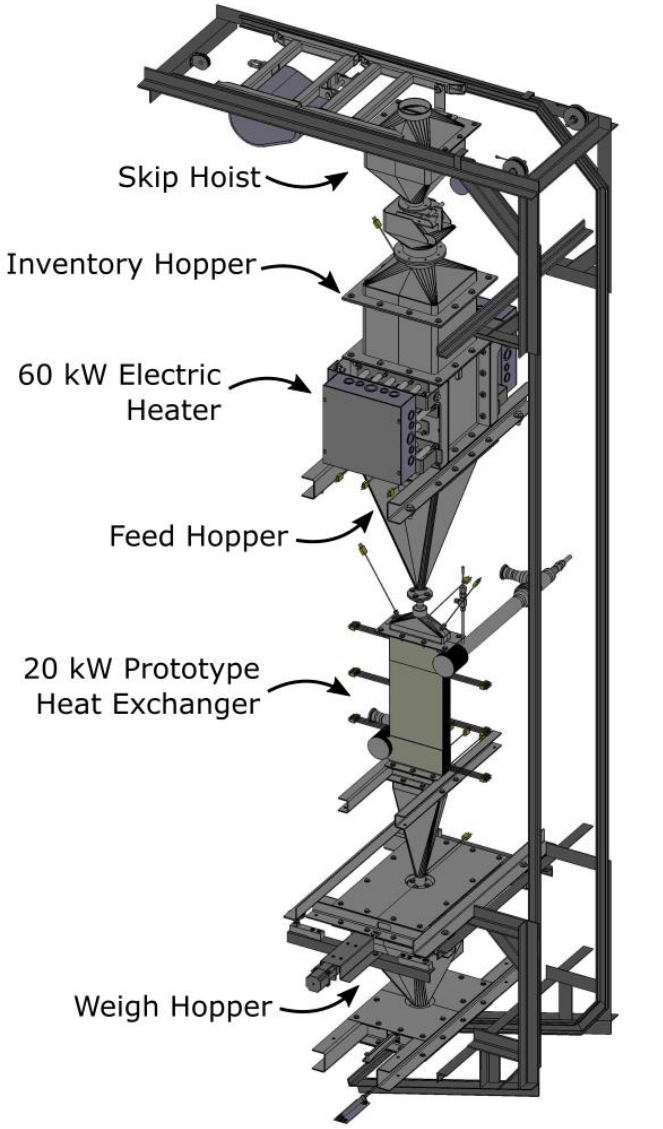
- Model performance is based on stochastic analysis considering uncertainty in input parameters (conductivity, near-wall resistance, flow uniformity, sCO_2 HTC)
- Expected overall heat transfer coefficient is **603 W/m²-K** based on input parameters verified against 20 kW data or **526 W/m²-K** based on 90% confidence level

Heat Exchanger Test Facility Upgrades



Revised Particle and sCO_2 Flow Loop Geometric Design





sCO_2 Flow Loop Assembly and Commissioning

- System has been operated up to temperatures of 500 ^{o}C using electric heat addition at 200 g/s and 17 MPa
- Recuperator and cooling heat exchangers appear to be over designed and within pressure drop allocations
- Pump performance map matches vendor data corrected for sCO_2 properties
- Electric heater is controllable and doesn't show any evidence of local hot spots

Particle Flow Loop Assembly and Commissioning

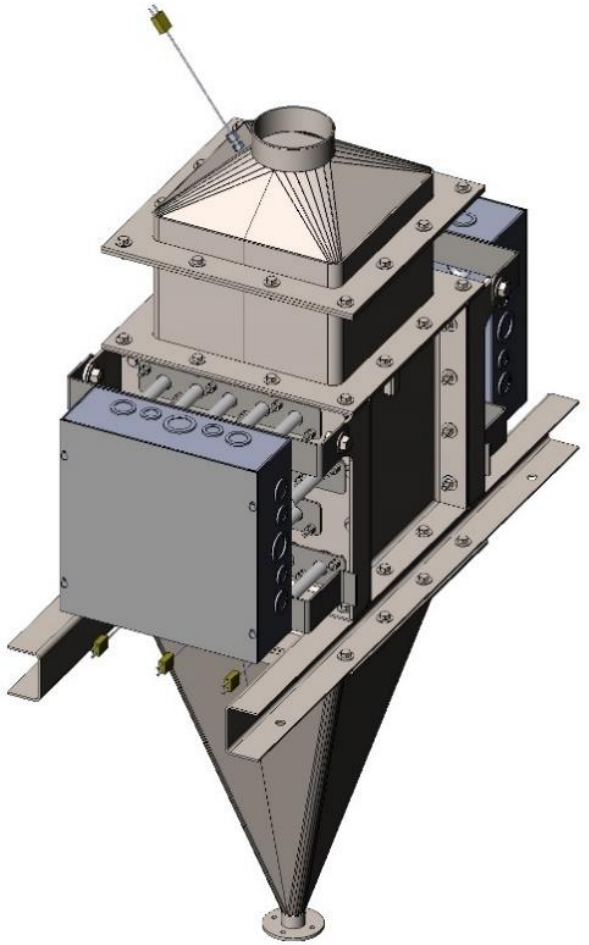
- Particle system has been assembled with third-party prototype heat exchanger installed
- Skip hoist has been installed and integrated with LabVIEW control system and demonstrated up to 300 ^{o}C at 200 g/s
- Revised weigh hopper design has been installed and used as feed hopper for skip hoist
- Final item to be modified is the particle heater upgrade to achieve temperatures up to 800 ^{o}C

Skip Hoist System Integration

Design Requirements:

- Maximum flow rate: 300 g/s
- Operating temperature: >600 ^{o}C
- Particle inventory: 22 kg
- Cycle time: < 75 s
- Lift height: 14 ft (vertical)
- Agnostic to particle type
- Incorporate horizontal conveyance
- Low particle abrasion

60 kWt Particle Electric Heater



- Electric heater design uses cartridge heater elements to create a shell-and-tube geometry
- Heater element count based on heat flux limitation for particle heat transfer coefficient

Summary

Revised particle and sCO_2 flow loop assembly and commissioning has been completed up to temperature of 500 ^oC and operating pressures of 17 MPa

Particle-to-sCO_2 heat exchanger with Gen3 operating conditions is nearing manufacturing completion

Testing of the particle-to-sCO2 heat exchanger at Gen3 operating conditions should be completed in the last quarter of 2022

Acknowledgements

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