Design of a Fluidized Bed Trim Heater

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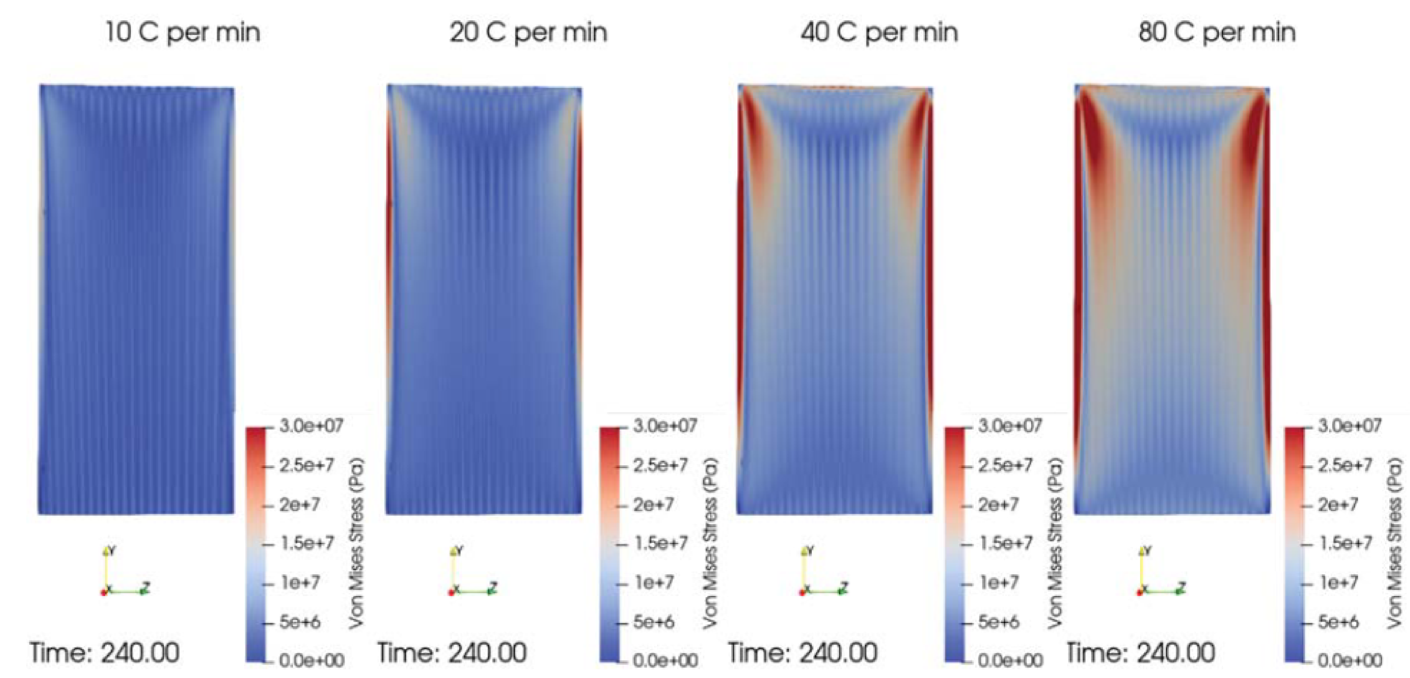
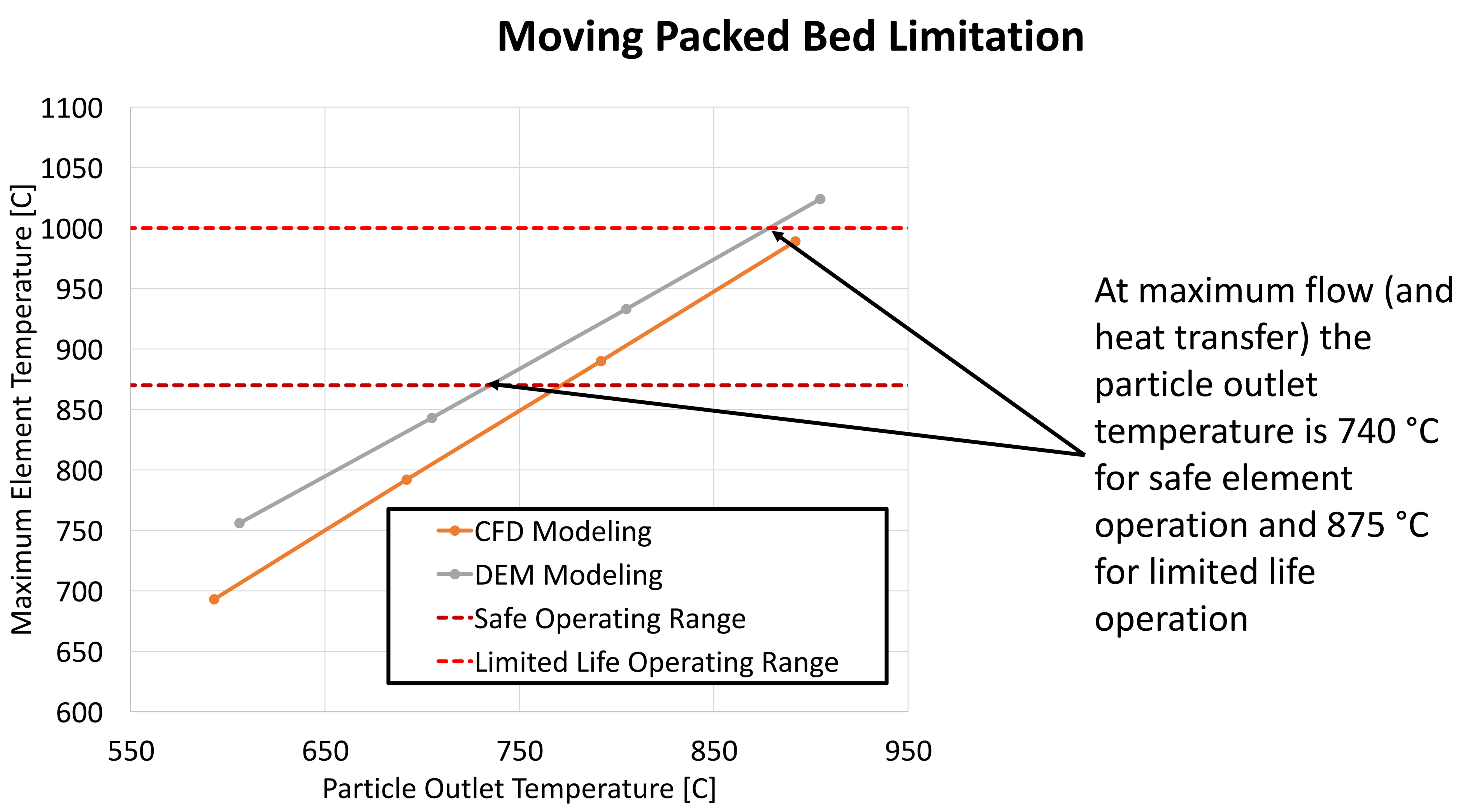
- The Generation 3 Particle Pilot Plant (G3P3) will feature a number of subsystems designed to provide stable plant operation and component safety including a 100 kW particle trim heater located upstream of the particle to sCO_2 heat exchanger.
- The packed bed particle trim heater was augmented to provide fluidizing air to the particle bed to increase the heat transfer coefficient from the cartridge heater elements.
- By fluidizing the particles, a larger change in particle temperature in a single pass through the trim heater is possible allowing for better thermal transient rejection.

Background

- The shell and plate primary heat exchanger is composed of parallel sCO_2 containing plates which transfer the heat from the particles to the sCO_2 working fluid.
- Parallel plate heat exchangers are particularly vulnerable to thermal shock due to the fully constrained plate architecture which can be stressed in the presence of large thermal gradients.
- A trim heater upstream of the heat exchanger allows for the rejection of temperature transients originating from the hot storage bin above.



DeLovato et al. "Thermomechanical Modeling of Counter-Flow Packed-BedParticle-to-sCO2 Heat Exchangers", SolarPACES 2020

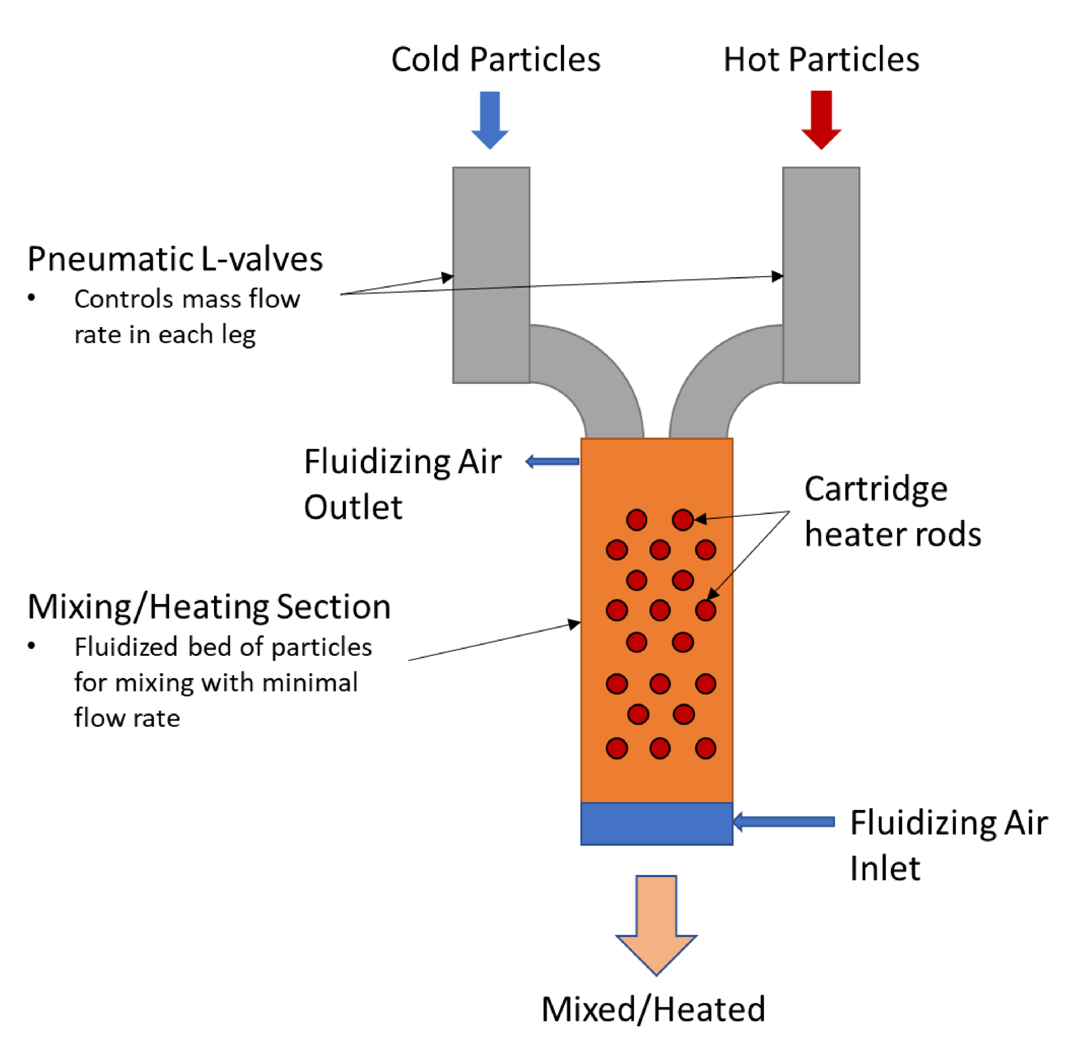


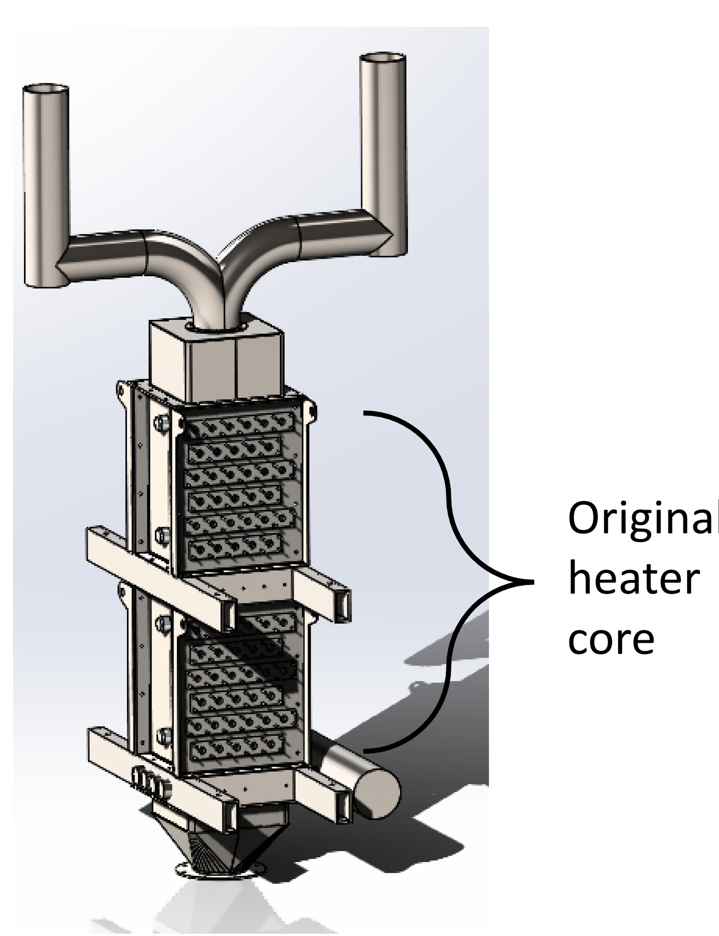
Fluidized vs Moving Packed Bed Heater

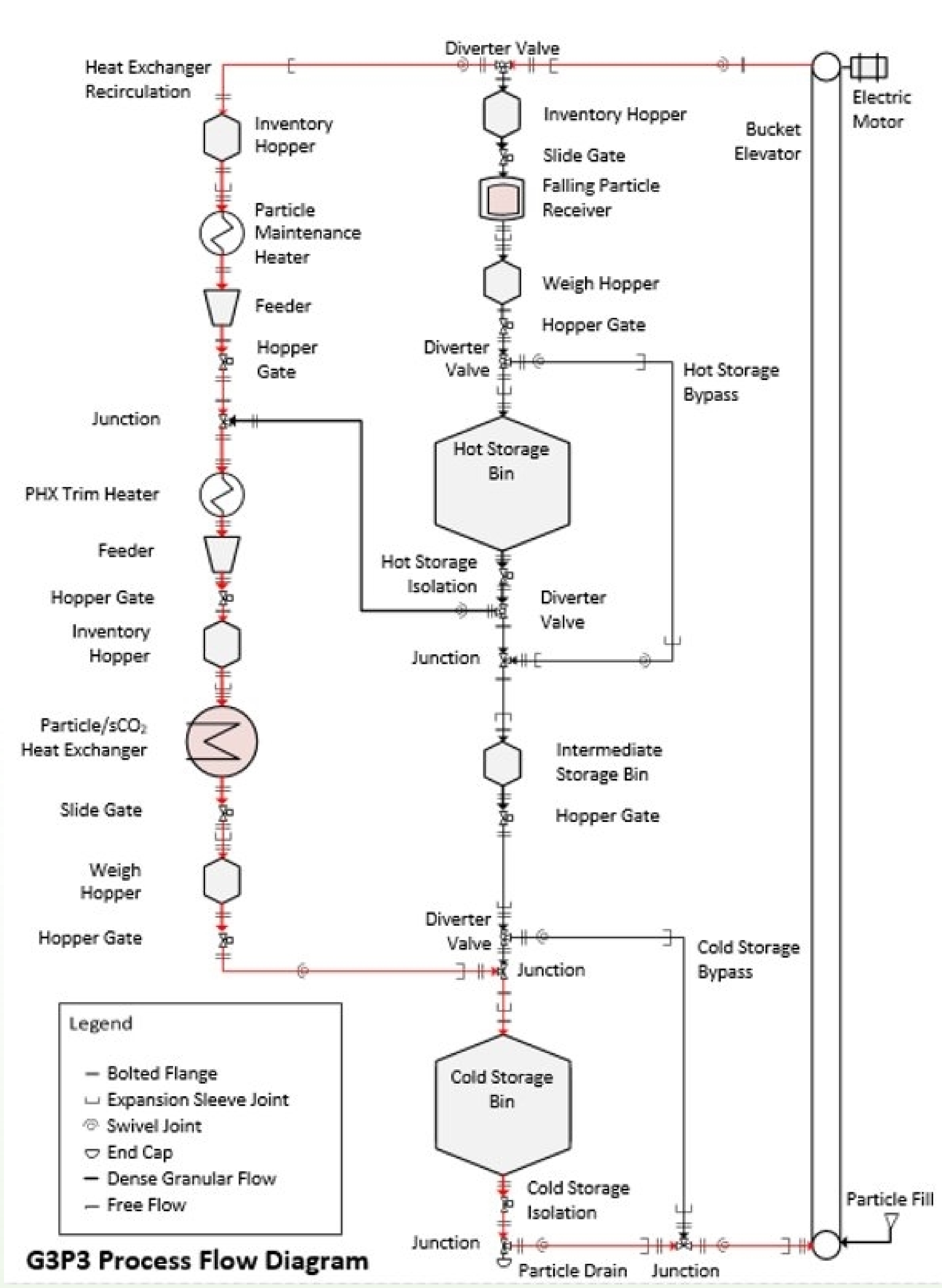
- The original trim heater core consists of a vertical section of ductwork with penetration through which cartridge heaters are immersed in the particle flow.
- A staggered array of cartridge heater rods with a maximum surface temperature of 870 °C directly contact packed particle flow with the duct.
- The moving packed bed heat transfer coefficient from the rods to the particles is dependent on particle flow rate.
  - At lower flow rates, the heat transfer coefficient decreases limiting the particle's ability to cool the rods to below their maximum temperature
  - Cartridge heater rods shut off to prevent overheating reducing total power delivered to particles.
- Fluidization provide a constant heat transfer coefficient, not dependent on flow rate, to allow for lower mass throughput and thus higher delta T.

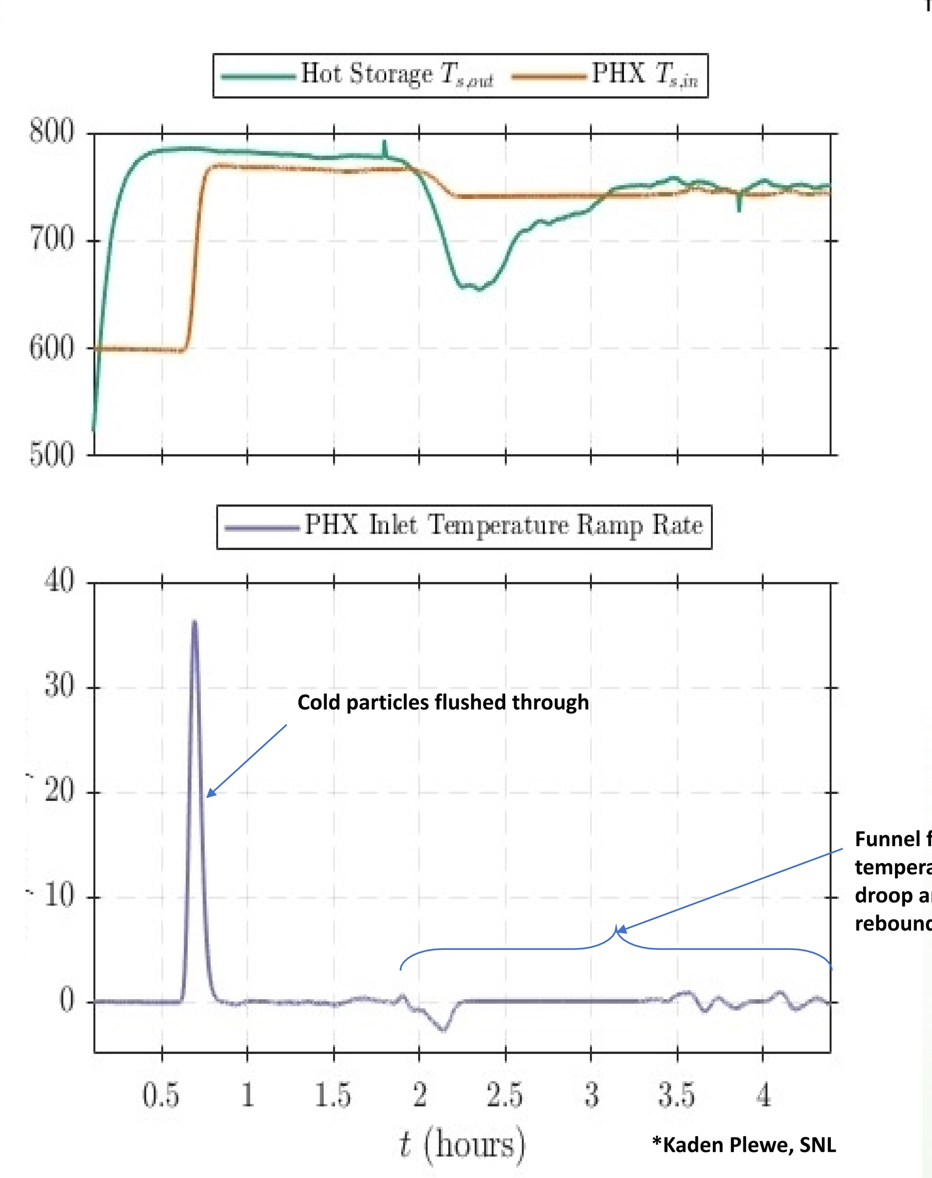
Fluidized Bed Heater Design

- Original particle heater core was reused with a new outlet hoper and support frame that included an air sparger
- The two inlets to the heater were converted to L-valves to prevent air ingress into upstream particle ductwork
- Fluidizing air reduces thermal duty by <5%









Additional Benefits

- The previous design required mass flow through the cartridge heater array to prevent hot spots at the heater's edges.
  - The tall mass flow cone was replaced with a shorter self drain cone making the fluidized system ~50% shorter.
- The fluidization mixes the particles allowing for blending of hot and cold particle streams from the hot and cold storage bins.
  - Particle temperature reduction can also be realized through fluidization without heat input.
- Low density debris in the particle stream will float in the fluidized bed making for easy filtration/separation.
- The trim heater will be used to heat air for hot storage bin maintenance heating when particles are not flowing through the heat exchanger.