



Thermal Performance and Effective Heat Transfer in a Vertical Electric Particle Heater for CSP

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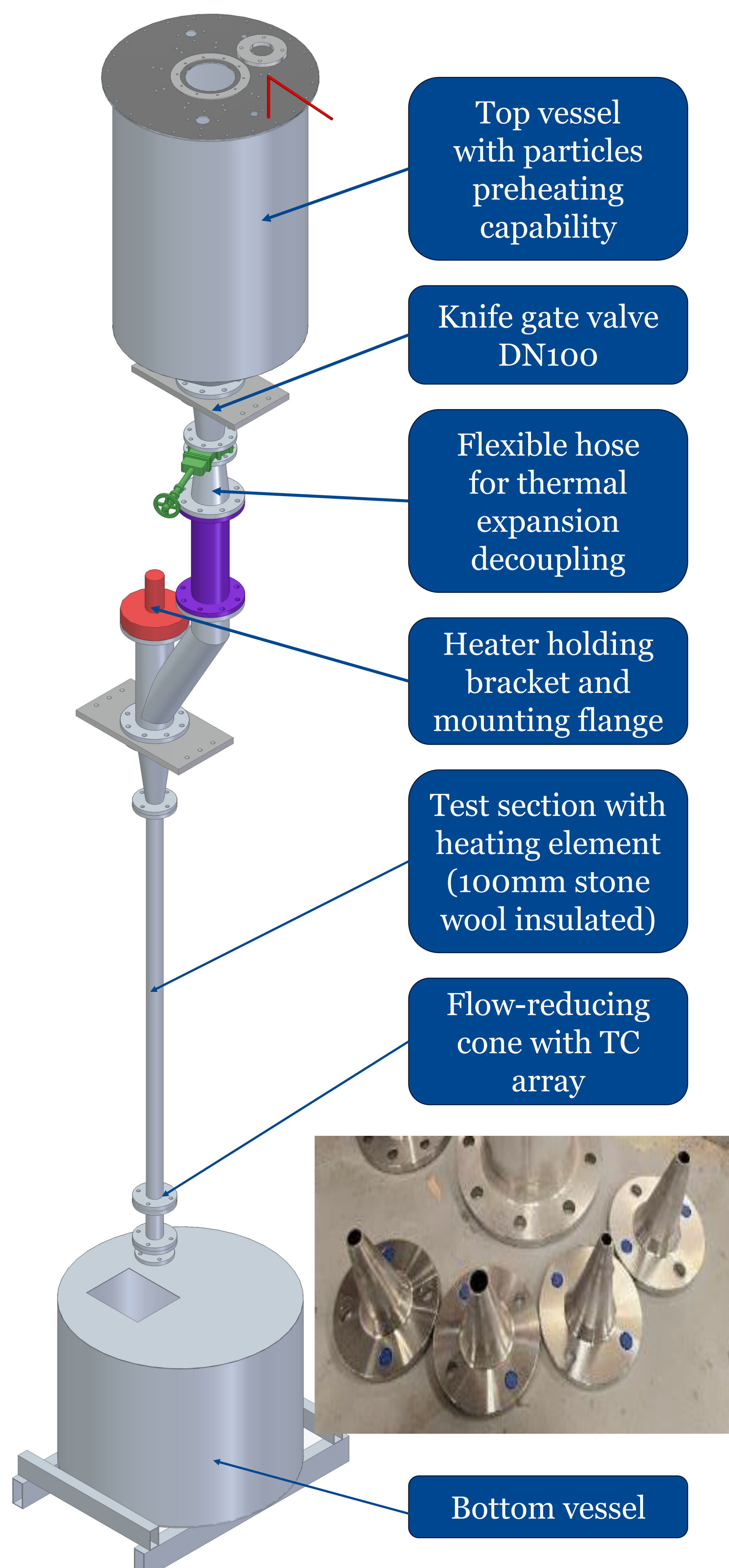
Within the POWDER2POWER project, a vertical electric heater (VEH) concept was investigated for additional heating of olivine particles in particle-based concentrating solar power and thermal energy storage systems. Particles descend by gravity through an annular channel surrounding a vertical heating element, while an outlet restriction controls discharge. This work presents the single-column experimental facility, and a revised assessment of its thermal performance, focusing on particle temperature uplift, outlet-temperature non-uniformity, and an LMTD-based effective heat-transfer coefficient.

Single-column VEH test rig at KTH

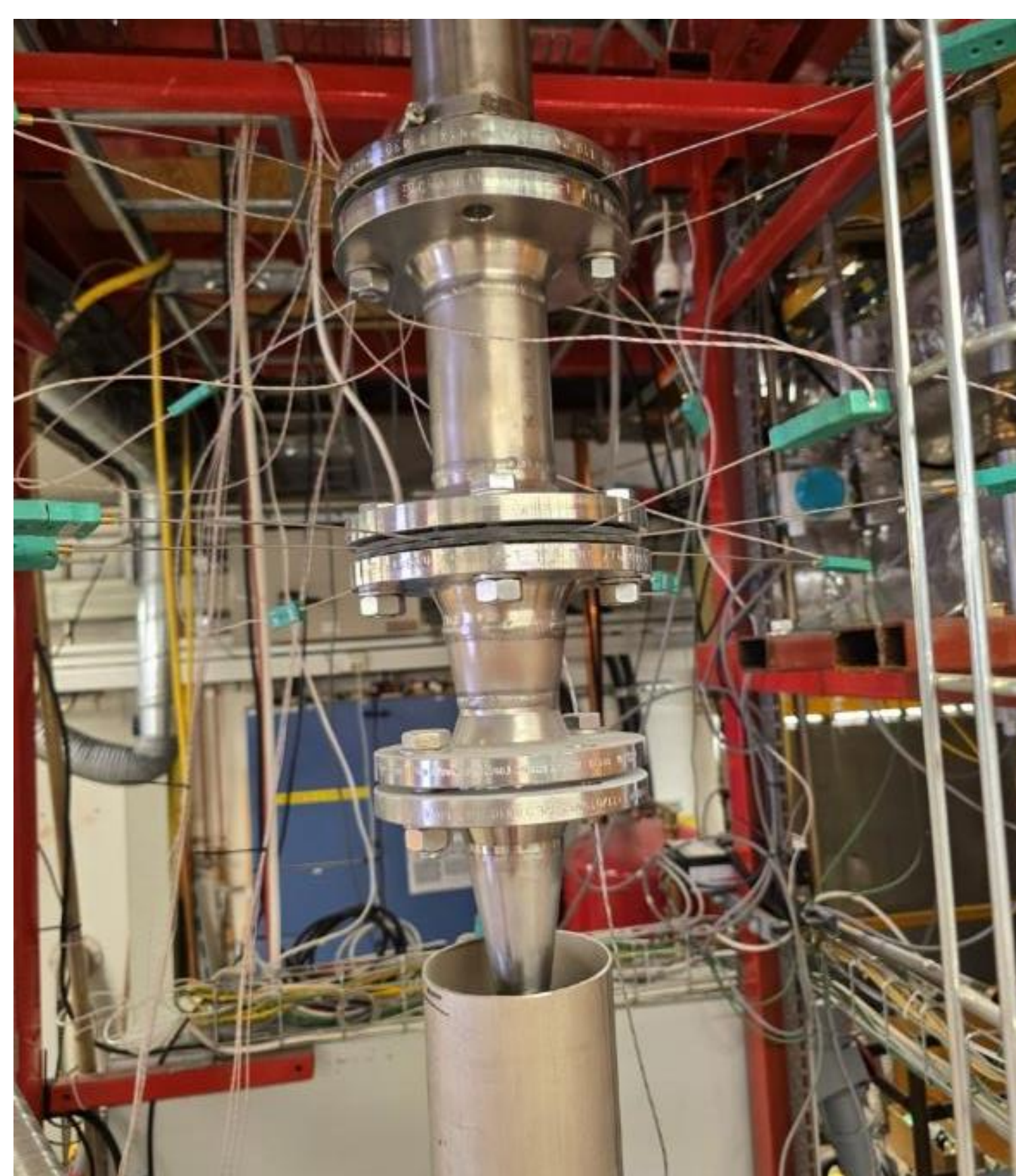
Olivine particles descend through a 9.65 mm annular gap (ISO DN65 pipe, OD=76.1mm, WT 2.9mm, SS304 1.4301) around a 51 mm heating element. The approximately 2 m heated section has a nominal power of 7.5 kW and a power density of 1.73 W/cm² (developed by SEICO).

Four heated-flow conditions were investigated using standard fixed-cone pipe sections as outlets with IDs of 13.2 mm, 15.1 mm, 17.2 mm and 20.1 mm.

Temperatures (inlet, outlet, heater surface) were measured with 20 Type-K thermocouples; particle discharge was measured gravimetrically. Particles entered near ambient temperatures. Particles tested: Olivine AFS 120 DS (Sibelco).



VEH outlet (fixed-cone) and TC array



Revised thermal assessment

Temperature and mass-flow records were synchronised and evaluated over selected stable operating windows.

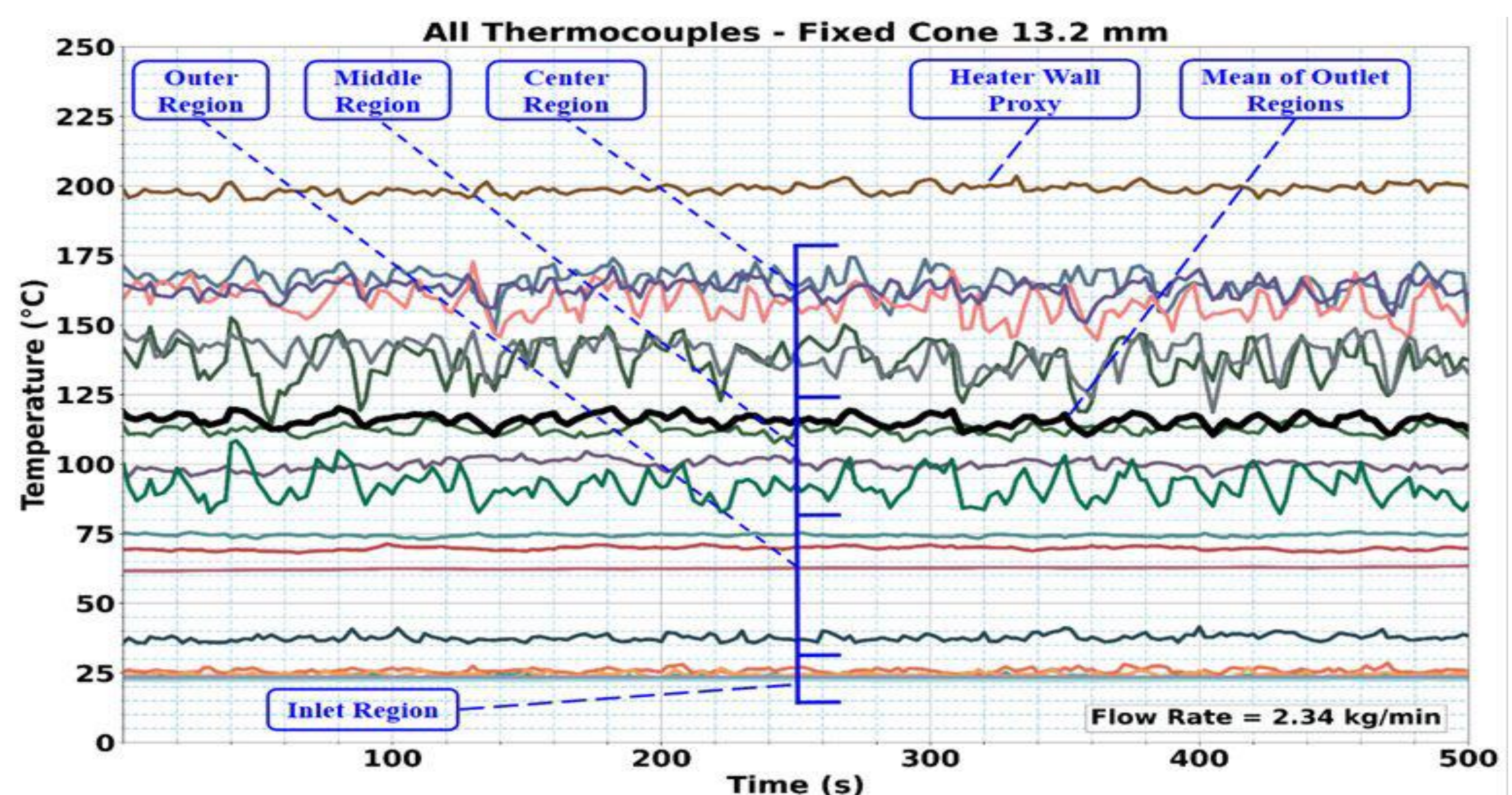
Outlet particle temperature was estimated from three equal-area radial regions right after the heater but before the outlet. This area-based estimate does not account for differences in local particle mass flux.

Particle heating power and effective heat-transfer coefficient were calculated as:

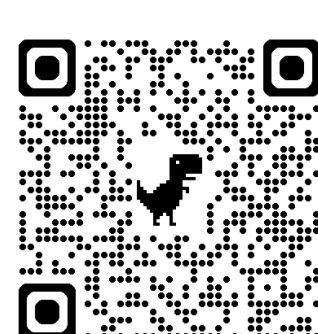
$$\dot{Q}_{abs} = \dot{m}c_p(T_m)(T_{b,out} - T_{b,in})$$

$$h_{eff} = \frac{\dot{Q}_{abs}}{A_h \Delta T_{lm}}$$

$$\Delta T_{lm} = \frac{(T_h - T_{b,in}) - (T_h - T_{b,out})}{\ln[(T_h - T_{b,in}) / (T_h - T_{b,out})]}$$



Want to know more?



Main results

The temperature-dependent heat capacity was evaluated at the mean inlet-outlet temperature. A single heater-temperature proxy T_h represented the surface temperature over the heated length, however it was measured only at one point near the outlet.

Consequently, h_{eff} is an effective operating-point parameter, rather than a directly measured local particle-wall coefficient.

Particle heating. Across four heated-flow operating points, mass flow ranged from 0.039 to 0.141 kg s⁻¹, with estimated temperature uplifts of 35–86.5 K. The highest uplift occurred with the 13.2 mm fixed-cone outlet at the lowest flow rate; but the 100 K objective was not reached.

Effective heat transfer. LMTD-based coefficients ranged from approximately 70 to 110 W m⁻² K⁻¹. Within each outlet type, higher flow coincided with lower temperature uplift but greater heating power and a higher effective coefficient up to certain particle moving speed. These results distinguish heating the particles to a higher temperature from transferring more thermal power to the particle stream.

Outlet ID	Flow rate	h_{eff} *
13.2mm	2.34kg/min	77 W/m ² ·K
15.1mm	3.08 kg/min	88 W/m ² ·K
17.2mm	4.01 kg/min	108.9 W/m ² ·K
20.1mm	5.51 kg/min	101.2 W/m ² ·K

*Type A uncertainty associated with temporal temperature fluctuations ~8 W/m²·K

Temperature non-uniformity. The spread between regional mean outlet temperatures was rather nonuniform. Measurement of bulk temperature after the outlet should be considered for next experimental campaigns.

Representative analysis window

Representative graphs of time-resolved temperature measurements shown for flow-reducing cones ID=13.2. The recalculated average bulk temperature is also plotted.