Thermal Stratification in Liquid Metal Pools Under Cold Transients

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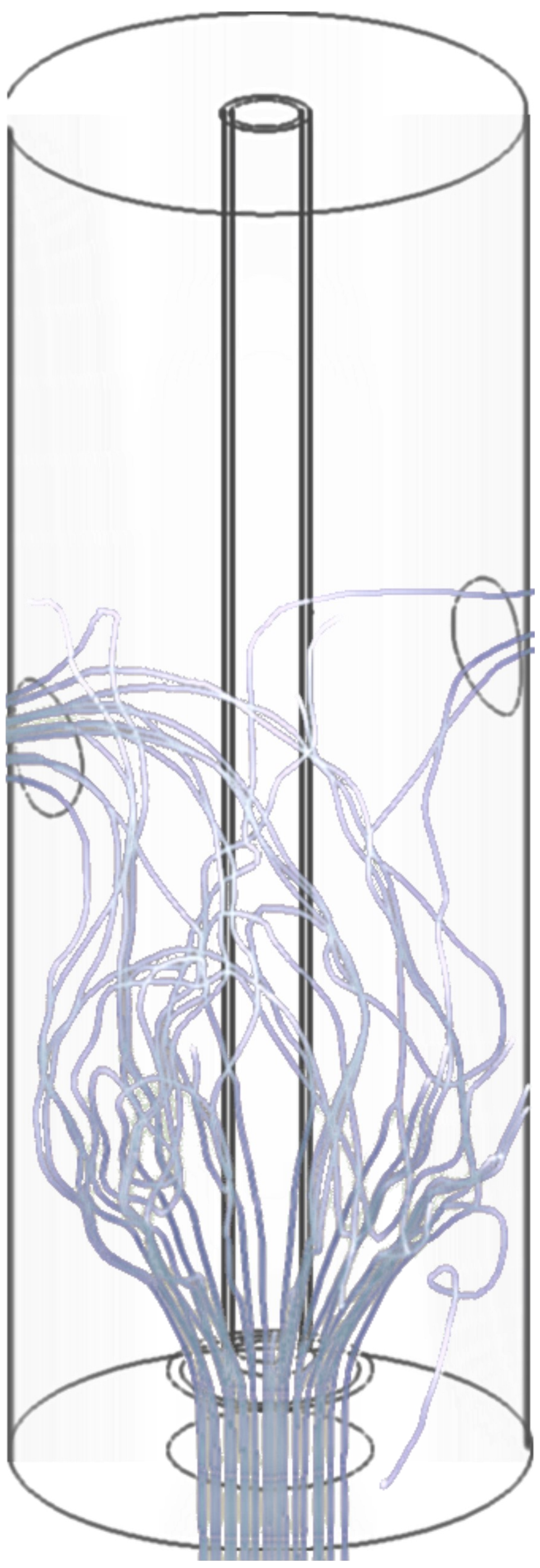

Experimental results are presented for understanding the thermal stratification or mixing in a low Prandtl number, Pr, pool due to the injection of a colder (higher density) jet at the bottom of the pool. In liquid metals (Pr<<1), the higher volumetric thermal expansion enhances buoyant forces, aiding in thermal stratification while the low Pr extends the thermal boundary layer. Rayleigh backscattering with swept wavelength interferometry is used to generate the high fidelity distributed temperature data. The high spatial and temporal resolution of the sensors are required to capture the temperature gradient and fluctuations of temperature allowing more complete understanding of thermal stratification front behavior. These fluctuations are characterized by their proximity to the critical flux Richardson number, where the ratio of buoyant dissipation to shear production of turbulent kinetic energy are equal:

$$Ri_{f,crit} \equiv \frac{-g\beta\overline{w'T'}}{\overline{u'w'}dU/dz} \equiv 1$$

This characterization provides insight into thermal stresses and fatigue in the adjacent solid structures of liquid metal pools but is insufficient to characterize the behavior in terms of global parameters. This is attributed to the liquid metals diverging from Reynolds analogy even at moderate Reynolds number flows, i.e. turbulent Prandtl number Pr_τ >1. Models developed by Weigand (*IJHMT* 40(17):4191-4196, 1997) (as modification to the Kays & Crawford model for Pr_τ for use with liquid metal) were validated experimentally. A parametric sweep of global parameters was performed to obtain the transition in stratification behavior from a planar to fluctuating interface; ie. buoyant dissipation equals turbulent generation or Ri_f = 1.

$$Ri_f = \left(\frac{-g\beta\frac{d\bar{T}}{dz}}{\left(\frac{dU}{dz}\right)^2}\right) \Bigg/ \left(\frac{\overline{u'w'}/\frac{dU}{dz}}{\overline{w'T'}/\frac{d\bar{T}}{dz}}\right) = Ri/Pr_\tau$$