# 3D LES of free convection from a side-heated vertical wall with cryogenic helium up to $Ra \sim 10^{15}$

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The passive safety concept of Small Modular Reactors (SMR) is based on the extraction of residual heat from the reactor to a surrounding water pool. However, the large scale of the reactor vessel (height≈15m) can lead to a rather intensive heat exchange process mostly by natural convection ($Ra \approx 10^{15}$). Reliable heat transfer correlations exist to date only up to $Ra \approx 10^{12}$, with uncertainties in the extrapolation to higher Ra. To improve the understanding of natural convection at high Ra number and find a valid heat transfer correlation, the three-dimensional turbulent natural convection boundary layer along a side-heated vertical wall is simulated through LES with the CEA in-house code TrioCFD[1]. The simulation has taken into account the local variations of the fluid properties. Near wall mesh discretization is enough refined ($y^+ \sim 0.2$) to resolve the thin boundary layer. Our preliminary analysis with water as a working fluid have shown the ability of the computational model in recovering the heat transfer behaviour[2] at moderate Rayleigh number ($Ra \approx 10^{12}$). As the second step, cryogenic helium is selected as a working fluid for its special physical properties (low viscosity, high $\beta$,…), which allows to reach high $Ra \approx 10^{15}$ in meter-sized experiments. The numerical results concerning the heat transport process show a good agreement with available reference data. Moreover, the mean temperature and velocity in the boundary layer are also presented. The vortex evolution in the boundary layer is visualized to enhance the understanding of the turbulence developing phases. Current work can shed more light on the understanding of the turbulent natural convection along a vertical wall at high Ra numbers. The numerical simulations will be complemented by a new experiment (Figure 1 below) currently under development at CEA aimed at reaching $Ra \approx 10^{15}$ using cryogenic helium to probe the boundary layer behaviour and statistics with μm-sized micro-fabricated hot & cold wires.

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[1] P.-E. Angeli et al, 16th Int. Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-16), 2015

[2] S. Yang et al SSRN Electronic Journal (Preprint), 2022, doi: 10.2139/ssrn.4009375.

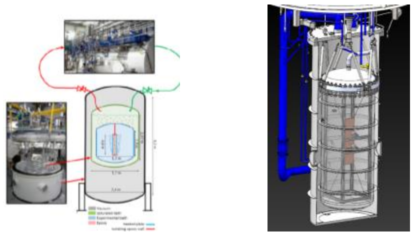

Figure 1 Left: configuration of the helium experiment: connection of the cryostat (bottom) to the refrigerator (top). Right: Sketch of the future test rig, with heated plate inside the pressurized cryostat.