Efficiency of Heat Transfer in High Rayleigh Number Cryogenic Helium Turbulent Convection

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Being motivated by contradictory results on Nusselt, Nu, versus Rayleigh, Ra, number scaling observed in various cryogenic Rayleigh-Bénard convection experiments, we have re-measured the $Nu(Ra)$ dependence for $7.2 \times 10^6 \leq Ra \leq 4.6 \times 10^{13}$ at $0.67 < Pr < 2.4$ using a cylindrical cell 0.3 m in diameter and height designed to minimize influence of its structure on the studied convective flow. High Ra are attained with cryogenic helium gas sufficiently far away from its critical point. The measured Nu values (both uncorrected and corrected with respect of adiabatic gradient and conductivity of wall and plates) obey, at least approximately, $Nu(Ra)$ power law scaling with exponent $\gamma \approx 2/7$ in the region $7.2\times10^6 \leq Ra \approx 10^{11}$ where $Pr < 1$; at higher Ra up to 4.6×10^{13} on slightly increasing Pr the power exponent approaches $\approx 1/3$ and does not indicate transition into ultimate Kraichnan regime. We show that, using an appropriate wall correction, the aspect ratio $\Gamma \approx 1$ Trieste, Grenoble and our cryogenic data sets collapse for $Ra < 10^{11}$. For $Ra > 10^{11}$ distinctly different $Nu(Ra)$ scaling is observed in various cryogenic $\Gamma \approx 1$ experiments that cannot be explained solely by the difference in Prandtl number, Pr – other reasons such as various quantitative measures of Boussinesq conditions must be considered. Local measurements of temperature fluctuations using small semiconducting sensors are also presented and discussed.