Thermal convection in dielectric liquids in a cylindrical annulus

INNOCENT MUTABAZI, CHANGWOO KANG, ANTOINE MEYER, Normandie Universite, MARTIN MEIER, CHRISTOPH EGBERS, Brandenburg University of Technology — Thermal convection is investigated in a dielectric liquid of thermal expansion coefficient $\alpha$, kinematic viscosity $\nu$, thermal diffusivity $\kappa$ and electric permittivity $\varepsilon$ in a cylindrical annulus of inner radius $a$ and outer radius $b$ with a radial temperature gradient and a high-frequency electric tension. The coupling between the electric field and the gradient of the permittivity yields the dielectrophoretic force. The control parameters are $\eta = a/b$, $Pr = \nu/\kappa$, the classic Rayleigh number $Ra = \Delta T g d^3/\nu \kappa$, and the electric Rayleigh number $L = \alpha \Delta T g_e d^3/\nu \kappa$ The electric gravity $g_e$ is the gradient of the electric energy in the condenser. Linear stability analysis shows that for infinite annulus, depending on values of $\eta$, $Ra$ and $L$, critical modes are either hydrodynamic or thermal modes, helical electric modes or columnar vortices. Experiments in an annulus of aspect ratio $\Gamma = 19.6$ during parabolic flight campaigns indicate the existence of columns. Columnar vortices result from the competition between Archimedean buoyancy and dielectrophoretic force. Direct numerical simulations in the annulus of $\Gamma = 20$ show that the columnar vortices occupy the central part of the annulus, while near the end-zones the flow is laminar and dominated by an azimuthal vorticity.

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