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Convection and electrovortex flow in liquid metal batteries

JONATHAN CHENG, IBRAHIM MOHAMMED, BITONG WANG, University of Rochester, GERRIT HORSTMANN, Helmholtz-Zentrum Dresden-Rossendorf, DOUGLAS KELLEY, University of Rochester — As renewable power sources like wind and solar energy become increasingly relevant, so too does the challenge of energy storage. Liquid metal batteries (LMBs) - galvanic cells composed of multiple fluid layers - are a promising technology to this end. Two major flow forcings interact within LMBs: thermal convection, due to the presence of internal heating, and electrovortex flow (EVF), driven by diverging current densities. Though these flows have potential to both help and hinder the batteries' operation, their properties remain largely unknown. Here, we study convection and EVF in a new liquid gallium laboratory experiment. Using ultrasonic Doppler velocimetry measurements, we construct phase diagrams for the dominant flow modes and flow speed scalings over broad ranges of convective forcing, EVF forcing, and container shape. Internal heating in LMBs also enforces stable density stratification, which interacts with EVF in largely unknown ways. We address this interaction experimentally for the first time in this work. Results are compared to linear theory predictions for the onset modes of each forcing. Combined with previous theoretical arguments and experimental/numerical results, this study lays the groundwork for future LMB design.

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