

Thermal Diffusivity Prediction of Liquid Metals with an Applied Magnetic Field

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Accurate thermal diffusivity (conductivity) values of liquid metals and semiconductors are important for high fidelity materials processing and crystal growth processes. In addition, whether the Wiedermann-Franz relation holds for liquid metals and semiconductors is not clear from available thermal conductivity data. Previous low-gravity and sample orientation experiments indicate that convective contamination occurs in thermal conductivity measurements. The measurement of thermal diffusivity/conductivity requires that either a steady-state temperature gradient or a transient heat pulse be applied to the sample. During either of these conditions, buoyant (natural) convection is produced within the melt sample in the presence of gravity. We consider the effect of magnetic field damping to reduce convective contamination of thermal diffusivity measurements in terrestrial gravity. A two-dimensional, axisymmetric model is used. The thermal diffusivity is determined with a two-point temperature measurement algorithm that we previously developed. The output thermal diffusivity is calculated for molten sodium with varying sample sizes, magnetic fields (0.1 to 1 T), and heat pulse inputs. Assuming a perfectly isothermal starting liquid, convective contamination of liquid sodium does not become significant until the applied temperature gradient is about 5 K, and it then increases roughly exponentially. Thus, depending on the temperature gradient applied, the convective contamination can be rather severe and time dependent. The axial velocity is typically stronger than the radial velocities in any case of interest. The numerical results for a range of practical sample sizes and magnetic field strengths will be discussed.