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The Effects of Buoyancy on Thermophoretic Deposition of Aerosol Particles in a Laminar, Vertical Flow

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A mathematical model has been developed to study the effects of buoyancy on the thermophoretic deposition of submicron particles. The flow configuration under consideration consists of laminar gas flow in a relatively cold, vertical tube. Such flow systems are often used for aerosol flow reactors that are utilized for the production of fine ceramic powders, like aluminum nitride. Predicting the characteristics of the thermophoretic deposition are important since it is desired to decrease the deposition during the process in order to increase product yield. In this effort, the modeling of the thermophoretic deposition of aerosol particles consists of two steps. First, the temperature and velocity of the continuous phase are predicted at every point within the tube by solving the mass, momentum and energy balance for the fluid phase. Second, using these profiles as inputs, the concentration of the particles and the level of deposition are predicted via an aerosol population balance, which accounts for the effects of particle convection and thermophoresis. In this model, the particles are assumed to be monodisperse. The effects of buoyancy have been found to slightly increase the overall deposition level of downward flow as compared to the case of upward flow. A more dramatic effect has been observed in the deposition as a function of axial distance. More particles are deposited at a shorter distance in downward flow through a vertical pipe than in upward flow. This behavior is primarily due to the tendency of buoyancy to "flatten" the downward flow velocity profiles, which allows the particles more time to deposit on the walls of the reactor. It should be mentioned that buoyancy in downward flows also leads to reduced temperature gradients, which will lessen the amount of particle deposition. This latter effect, however, is not great enough to overcome the increased residence time of the particles. Hence, both the overall and local deposition levels are found to be greater for the downward flow case.