Boundary layer approach to heat transfer rate to cold cap

Pavel Hrma*[1], Seungmin Lee[1], Richard Pokorny[2], Joseph Traverso[1], Jaroslav Klouzek[2], Michael Schweiger[1], and Albert Kruger[3]

[1]Pacific Northwest National Laboratory – United States
[2]University of Chemistry and Technology Prague – Czech Republic
[3]U.S. Department of Energy, Office of River Protection – United States

Abstract

In an electric glass melter, the heat flux needed to maintain the steady state is a product of the feed to glass conversion rate (the rate of melting) and the conversion heat. On the melt side at the cold cap bottom, the heat flux is a product of heat conductivity of melt and the temperature gradient. On the cold cap side, this heat flux has to be transferred across foam layer to the main reaction layer. The boundary layer approach allows approximating the temperature gradient in the melt as the difference between the melter operating temperature and the cold cap bottom temperature divided by the thermal boundary layer thickness, which is a function of melt viscosity and the bulk velocity. In advanced melters, such as those for nuclear waste vitrification, the melt velocity is enhanced by bubbling gas into the melt pool. Thermal gravimetry, differential scanning calorimetry, evolved gas analysis, and volumetric analysis (the feed expansion test) are the main experimental tools to gauge the melter feed response to heating, including foam formation and collapse. A large variability exists in the foaming response depending on the feed composition and makeup. The boundary layer approach allows combining experimental data and empirical correlations into a simple relationship between the rate of melting and the governing parameters, i.e., melt viscosity, gas bubbling rate, conversion heat, and the foam collapse temperature. Thus, it can serve as a link between the mathematical model of the cold cap and the mathematical model of the momentum, heat, and mass transfer in the glass melt body.

Keywords: glass melting, cold cap, heat transfer, boundary layer

*Speaker